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The Netley-Libau Marsh Fish Resource

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EXECUTIVE SUMMARY

Netley-Libau Marsh provides spawning, nursery and feeding areas for Lake Winnipeg and Red River fish populations supporting three of Manitoba's largest, most profitable fisheries. Experience on Canada's Great Lakes and elsewhere has shown that marshes affected by pollution, filling, drainage and poorly planned hydraulic engineering are often a cause of serious declines in fish harvests. Netley-Libau Marsh's 24000 ha represent the largest marsh environment bordering Lake Winnipeg and the only significant intermediate delta on a major tributary, the Red River. Protection of Netley-Libau Marsh should therefore be considered. Top priority should be given to assuring that waterways connecting Netley-Libau Marsh, Lake Winnipeg, and the Red River are kept free from engineering works which interfere with natural flooding patterns and fish movements.

This study indicates that abundant fish populations occur in Netley-Libau Marsh during Spring and Summer. A reasonably rich fauna of at least twenty-five species occurs in Netley-Libau Marsh with eight cool or warmwater adapted species or genera being abundant. There are two distinct open water species compositions. In Spring, the fish community is best described as a spawning species assemblage. In Summer, the fish community is best described as a feeding species assemblage. Young-of-year fish are abundant during Summer, not only from species which spawn in Netley-Libau Marsh, but also from species

whose eggs and larvae probably reach it by passive drift. In Fall, there is a decline in the number of species occupying Netley-Libau Marsh. In Winter, much of Netley-Libau Marsh is frozen to the bottom and most fish species are apparently forced into the Red River and Lake Winnipeg although some species are able to over-winter in deeper marsh channels.

Large scale fisheries do not occur in Netley-Libau Marsh itself but fish species occurring in the marsh are valuable to the Lake Winnipeg commercial gillnet fishery which harvests 37% of Manitoba's total fish production, the Red River sport fishery which receives 15-20% of resident angling effort and the Red River - Lake Winnipeg bait fishery which produces 60-70% of Manitoba's bait fish production. The most valuable abundant Netley-Libau Marsh fishes are northern pike *(Esox lucius)*, yellow perch *(Perca flavescens)*, sauger *(Stizostedion canadense)*, shiners *(Notropis* sp) and goldeye *(Hiodon alosoides)*.

Northern pike are one of the most sought after sport species while Lake Winnipeg produces 17% of Manitoba's annual commercial pike production. Northern pike overwinter in the channels of Netley-Libau Marsh. Northern pike require freshly flooded vegetation to spawn making Netley-Libau Marsh a valuable spawning habitat. Netley-Libau Marsh probably acts as a northern pike nursery but this has not been documented to date. After spawning in Spring, northern pike become less abundant and many individuals may leave the marsh for the Summer. Northern pike appear to return to Netley-Libau Marsh in the Fall.

Yellow perch at present have a higher value per kilogram than the better known commercially and recreationally valuable walleye *(Stizostedion vitreum)* and sauger. Lake Winnipeg provides 78% of Manitoba's annual commercial perch production. Yellow perch spawn during Spring over a variety of substrates but submerged and flooded vegetation are among the most important. Yellow perch show evidence of spawning in Netley-Libau Marsh and their offspring use the marsh as a nursery. Young-of-year yellow perch provide important forage for walleye and sauger. Along with abundant populations of shiners, young-of-year yellow perch are thought to be responsible for a summer feeding migration of sauger into Netley-Libau Marsh. Adult yellow perch also appear to use Netley-Libau Marsh extensively for feeding in Summer. Yellow perch appear to leave Netley-Libau Marsh in Fall.

Lake Winnipeg's sauger fishery is probably Canada's most productive while the Red River sport fishery produces more trophy size sauger than any other Manitoba waters. Sauger do not appear to use Netley-Libau Marsh for spawning to any great extent but the marsh appears to be a valuable feeding area during Summer. Sauger do not appear to overwinter at Netley-Libau Marsh.

Aside from their role as forage for commercially important fish species, shiners are the major product of the Lake Winnipeg-Red River bait fishery. Little is known of shiner biology in the Netley-Libau area but the abundance of shiners in summer both as adults and young-of-year implies that Netley-Libau Marsh acts as a nursery.

Goldeye use Netley-Libau Marsh as a nursery and feeding area. Spawning use of Netley-Libau Marsh by this species is indicated but has not been documented to date. Consumer demand for goldeye regularly exceeds supply. Lake Winnipeg was once the major Canadian producer but the fishery collapsed after 1938. The Red River is at present the second most valuable Manitoba sport fishing water for trophy size goldeye.

The fisheries ecology of Netley-Libau Marsh is typical of shallow water zones associated with both a river and a lake. Inflowing streams leach nutrients from the land through which they flow. The shallow water zone traps them resulting in high nutrient concentrations. High nutrient levels support a large food base in the form of rooted vegetation and phytoplankton which in turn supports abundant populations of higher organisms such as zooplankton and fish. At Netley-Libau Marsh potential fish standing crop based on total phosphorous, a key growth nutrient, is about 279-384 kg/ha. Potential sustainable fish harvest is 17-27 kg/ha. These values are about 3-4 times greater, on a unit area basis, than similar estimates for Lake Winnipeg's south basin. Seasonal river flows and seasonally fluctuating lake water levels from wind induced seiches constitute an energy subsidy not only by bringing in nutrients but by removing wastes and exporting phytoplankton, zooplankton and organic materials to the surrounding waters. This prevents stagnation and enhances productivity in surrounding waters. Shallow depth allows rapid warming and continuous wind mixing resulting in temperature and oxygen regimes which provide physiologically

excellent growth conditions. These attributes make the shallow water zone an excellent spawning nursery and feeding area. Shallow depth, however, also imposes a seasonality on fish populations. The winter freezing of marsh lakes creates conditions which may result in winterkill if fish cannot escape to deeper waters.

A literature review shows that shallow water zone characteristics are often overlooked with unfortunate fisheries consequences. An 82% reduction in the Missouri River fish catch for example has been attributed to a 67% loss of shallow water habitat adjacent the main river channel. Similarly, declines in the value of Canada's Great Lakes fisheries have been attributed to improper peripheral wetland management. Shallow water zone losses are caused by pollution, partial or complete drainage, ditching and canal construction, dyking and ponding, and water level stabilization projects. Most often these activities make shallow water zones inaccessible to fish resulting in less total spawning, nursery and feeding area available for wetland dependent fish stocks.

Existing aquaculture and fish husbandry techniques are not sophisticated enough to provide adequate mitigation for loss of fish access to the marsh complex. Recommended fisheries management for shallow water zones calls for the preservation of natural fish use patterns with top priority being given to keeping shallow water zones free of pollution and engineering works such as levees, polders, embankments and non-passable water control structures.

Given the large size of Netley-Libau Marsh and the import-

ance to Manitoba's fisheries of the fishes which use it, it is recommended that the above management strategy be applied to the Netley-Libau Marsh.

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INTRODUCTION

In 1980, Manitoba's Wildlife Branch began to examine the feasibility of developing the Netley-Libau Marsh for increased waterfowl and furbearer production. Waterfowl and furbearer production is said to be lower than expected due to wind driven water level fluctuations within the marsh. This situation is aggravated by water level regulation of Lake Winnipeg since 1975 (Townsend 1969; Parlour et. al. 1972; Lake Winnipeg, Churchill and Nelson Rivers Study Board 1975; Lake Winnipeg Marshes Working Group 1977). Under regulation the range of extreme Lake Winnipeg water levels is reduced while the long term mean level is raised by 0.20m to 217.63m above sea level (Lake Winnipeg, Churchill and Nelson Rivers Study Board 1975). The Lake Winnipeg Marshes Working Group (1977) suggested that wildlife production could be improved by:

1. increasing the land to water ratio through construction of islands
2. the maintenance of suitable water level regimes through construction of dykes and compartments
3. stabilization of shorelines
4. planting of appropriate nesting cover
5. provision of staging areas and nesting structures

To assess the applicability of these methods, the Wildlife Branch requested up to date resource descriptions for Netley-Libau

Marsh.

The Fisheries Branch established four objectives for a description of the fish resource. These were to:

1. describe fisheries related physicochemical features of the Netley-Libau Marsh and determine its suitability as a fish habitat

2. describe the fish community associated with the Netley-Libau Marsh

3. identify fisheries associated with the Netley-Libau Marsh

4. comment on the fish resource in relation to marsh development for increased waterfowl and furbearer production

Prior to 1980, the Netley-Libau Marsh fish resource had not been formally described. McLeod and Moir (1944 a,b) investigated the effect of carp on vegetation and muskrat populations of Netley-Libau Marsh. Johnson (1970) commented on the theoretical fisheries value of Netley-Libau Marsh. The Lake Winnipeg Marshes Working Group (1977) described the Netley-Libau Marsh and with noted exceptions their description is summarized as part of this report. The preliminary development concept (Moulding 1979) for Netley-Libau Marsh is also summarized as part of this description. Fisheries theory pertaining to Netley-Libau Marsh is presented in a literature review. Fisheries Branch surveys from 1980 and 1981 provide fisheries related physicochemical features, fish community and fisheries information specific to Netley-Libau Marsh. A comment on the fish resource in relation to marsh development is included in a discussion of the study area description, the literature review and fisheries survey results.

DESCRIPTION OF STUDY AREA

The Netley-Libau Marsh (96°30'-97°00' long., 50°15'-50°30' lat.) is the delta of the Red River at its point of entry to Lake Winnipeg (Fig. 1). The Marsh's 17 major lakes, the low lying land surrounding them and their connecting channels form the largest of Lake Winnipeg's peripheral marshes (Townsend, 1969).

The existing 24000 ha of the Netley-Libau Marsh was covered, in post-glacial times, by Lake Agassiz. The bedrock is composed of glacial shale deposits and Ordovician limestone. Clays and silts deposited by Lake Agassiz overlie the bedrock. The further deposition of sediments and reworking of existing sediments, in recent times, by the Red River and Lake Winnipeg have resulted in a complex of channels, reversed deltas, natural levees and a beach ridge which form an intricate pattern of marsh land and lagoons. The marsh is not a delta in the normal sense of the word since most sediments are not directly deposited by the Red River (Unies Ltd. 1972). The primarily fine grained river sediments are held in suspension by currents and wave action in Lake Winnipeg (Unies Ltd. 1972). Sediments deposited in the Netley-Libau Marsh reach it mainly through openings in the beach ridge of Lake Winnipeg's southern shore (Unies Ltd. 1972).

Bottom soils are a composition of inorganic muds, muck and peat overlying muck.

Common emergents consist of cattail *(Typha* sp.), common reed grass *(Phragmites communis)*, reed canary grass *(Phalaris* sp.)

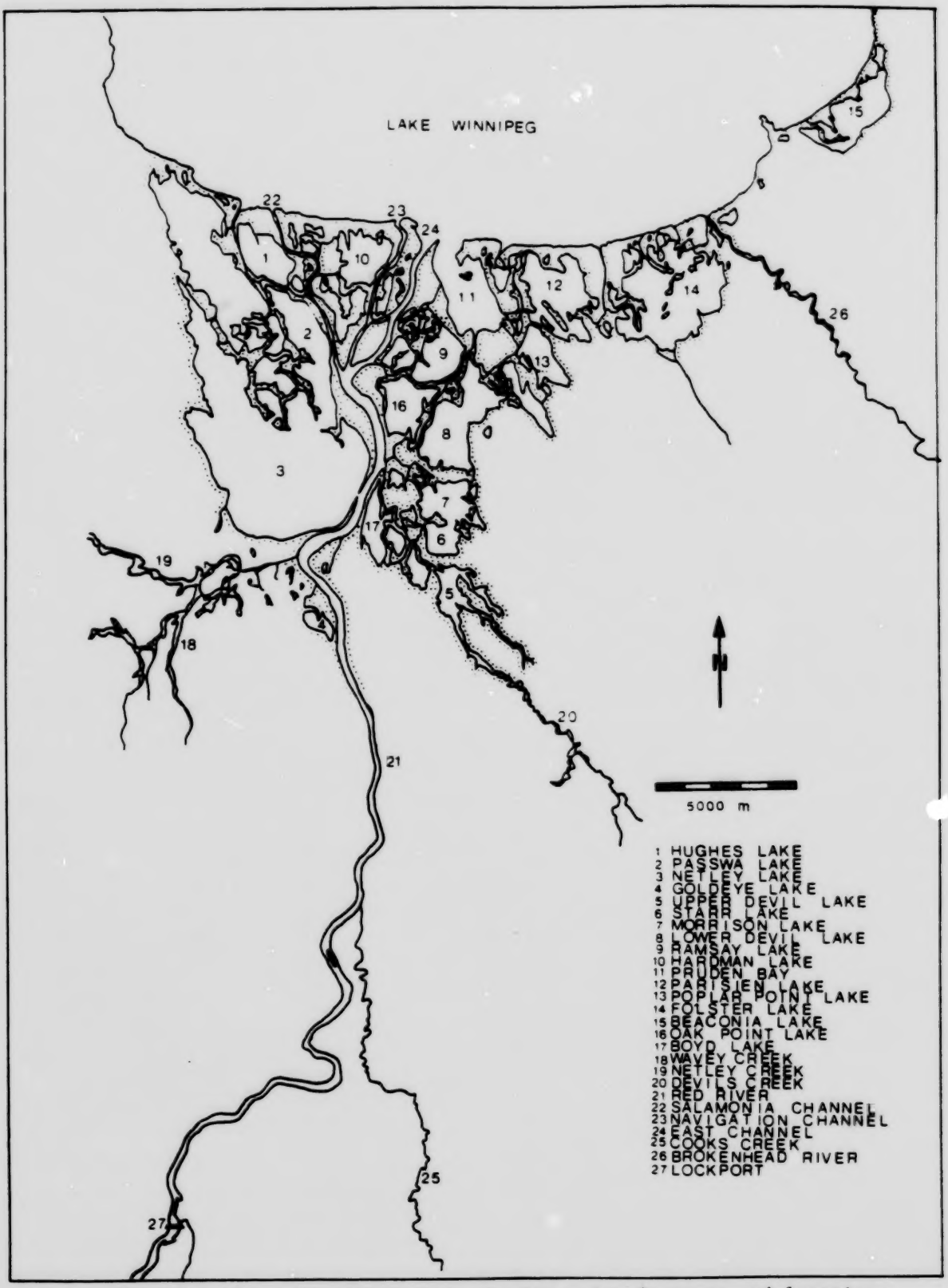

Fig. 1. Map of Netley-Libau Marsh area showing major features and locations mentioned in text.

and bullrushes (*Scirpus acutus, S. validus, S. fluviatilis*).

Common submergents include water milfoil (*Myriophyllum* sp), bladderwort (*Utricularia* sp), sago pondweed (*Potamogeton pectinatus*), floating leaf pondweed (*P. natans*), mares tail (*Hippuris* sp) and water lily (*Nuphar* sp).

Weather characteristics involve large seasonal temperature ranges and moderately dry conditions. Marsh freeze up occurs during mid November with spring breakup during May. Mean annual temperature is $\sim 2^{\circ}C$ with a frost free period of 100-111 days. Annual precipitation is $\sim$ 48-51 cm of which $\sim$ 70% falls as rain between April and October.

Water resources consist of inter-connected lagoon-type lakes and tributary streams. Townsend (1969) reported that the Netley-Libau Marsh had 50 lakes covering an approximate total area of 8 094 ha during the 1940's. High water levels on Lake Winnipeg in the late 1960's reduced the number of lakes to 17 and increased open water area to an estimated 12 141 ha (Townsend 1969). Major tributaries are the Brokenhead River, Netley Creek, Devils Creek and the Red River.

Water levels are influenced by tributary flows and on a broader scale by Lake Winnipeg itself. Long term water levels are similar on Lake Winnipeg and the Netley-Libau Marsh. Short term fluctuations in water level as great as 1m above mean water level occur as a result of wind setup on Lake Winnipeg.

Lake Winnipeg water levels have been regulated since 1975

for the production of hydroelectric power. Also, the Red River passes through seven dams in the United States, control structures for the Winnipeg floodway (periodically) and a low flow control structure and lock at Lockport, Manitoba, approximately 28 km upstream from Netley-Libau Marsh (Unies Ltd. 1972).

There was no rigidly defined study area for the present studies. However, according to the Lake Winnipeg Marshes Working Group Report (1977) "Major opportunities are associated with Marsh habitats separated from Lake Winnipeg by the beach ridge and from the Red River by levées. Sector studies should therefore, concentrate on these areas and recognize the possible need for separation of the Marsh from lake Winnipeg and the Red River. Upland areas and minor drainage systems such as the Brokenhead River, Devil, Wavey and Netley creeks should be considered in less detail".

The preliminary concept forming the basis for discussion was developed by Ducks Unlimited (Moulding 1979). The concept calls for compartmentalization of the Netley-Libau Marsh by constructing seven dyked cells with water control structures at critical points (Fig. 2). The main objective within each compartment would be to create a stable water level regime. A stable water level regime would create more wildlife habitat and stimulate increased wildlife use. Wildlife use is felt to be below basin potentials due to annual spring flooding, periodic within season flooding and turbidity. These factors are thought to limit submergent and emergent plant growth and create poor upland grass-forb communities. Spring runoff flooding would be

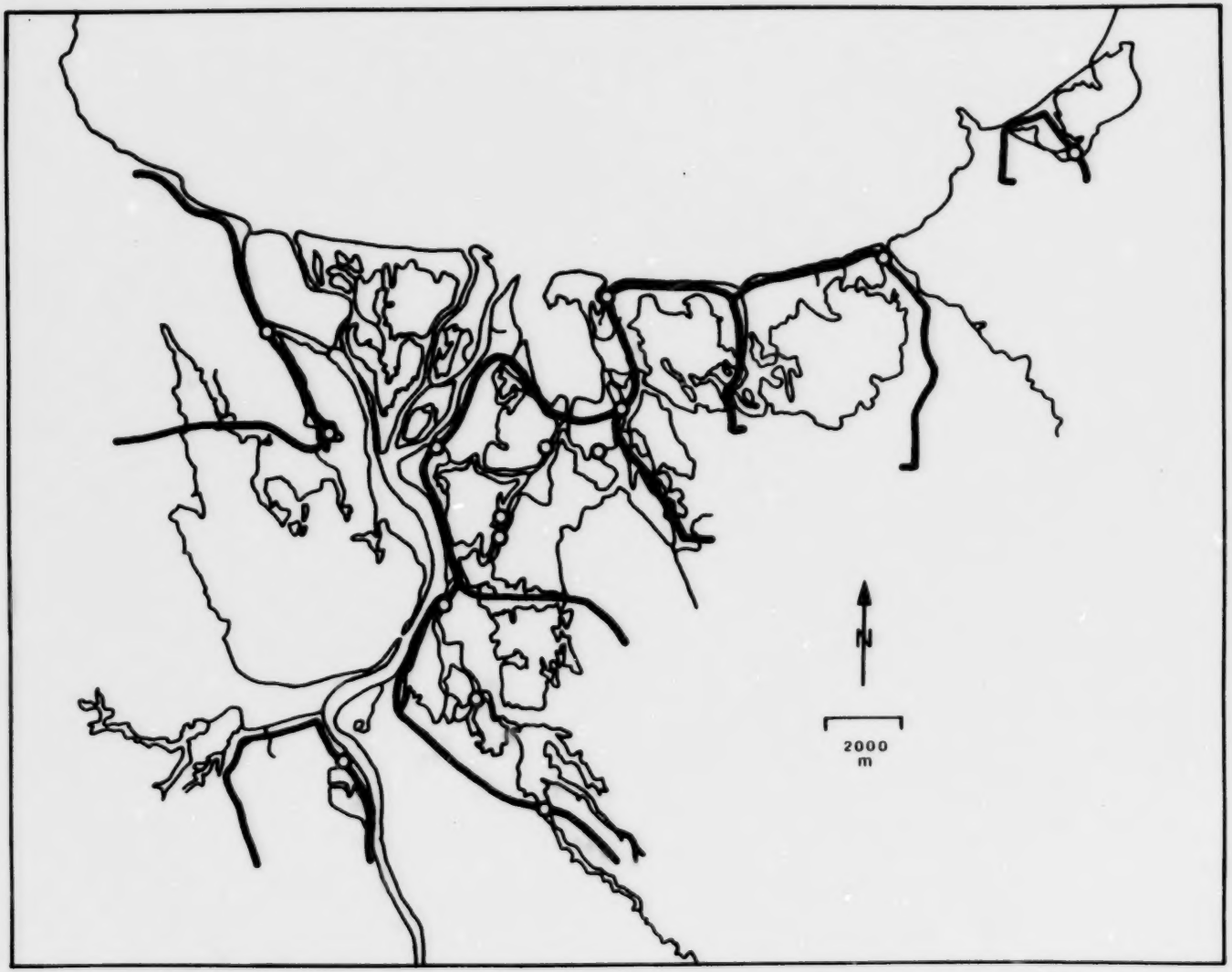

Fig. 2. Preliminary concept for development of Netley-Libau Marsh. Open circles show locations of water control structures. Heavy lines show dyking.

minimized by enclosing Netley-Libau Marsh lakes with ring dykes to reduce total drainage area. Within season flooding (due to wind surges) is addressed by the construction of dams across outlet channels. Each dam would contain one or more culverts. Culvert controls would allow free flow out of compartments when water levels exceed full supply level (FSL). Control structures would automatically close to prevent water level increases due to backflooding from the Red River. During low water periods compartments would be brought up to FSL by manually overriding automatic gates to allow backflooding from the Red River. If required, pumps would be employed in addition to backflooding. Although these measures would increase desired plant growth and reduce turbidity, complete drawdowns might take place every seven or eight years to further encourage growth of emergent vegetation. Prescribed burns would be used in upland areas to encourage desirable grass-forb communities. In addition, construction of nesting islands and nesting boxes within compartments might occur to create an additional waterfowl production capability.

The working group recommendation and the resulting development concept define the major area of interest for Fisheries Branch surveys at Netley-Libau Marsh. The development concept does not necessarily represent the development that will eventually be recommended since the Wildlife Branch wished for input from other resources before selecting a development scheme.

LITERATURE REVIEW

Deltas may arise wherever a river with a definite velocity and turbulence passes into a large volume of water of lower velocity and lower turbulance (Hutchinson 1957). Where wave action in the larger water body is insufficient, the suspended sediment load tends to settle as the velocity and turbulence are reduced and a recognizable delta is produced. In long narrow lakes (e.g. Lake Winnipeg), inflowing streams at the lake's upper end (e.g. the Red River) often develop deltaic deposits which fill the whole width of the lake producing a bay delta (Johnson 1919). In the process of delta formation, numerous deltaic levee lakes, among other types, may be formed (Hutchinson 1957). An area like Netley-Libau Marsh is a typical result of these processes.

Welcomme (1979) has divided deltas into three broad categories. Internal deltas occur in the course of a river where a geographical feature causes the river to spread laterally over an alluvial plain. An internal delta is defined when the main river channel is identifiable both above and below the deltaic area. Coastal deltas occur where rivers enter the sea. Coastal deltas are influenced by the tides and salinity of the marine environment. Areas like Netley-Libau Marsh fall into a third category. Deltas which occur where a river discharges into an inland freshwater lake are intermediate between internal and coastal deltas (Welcomme 1979).

Deltas located on rivers in which seasonal variations in

rainfall are transmitted downstream in one or more pulses of increased flow (flood as opposed to reservoir rivers) such as the Red River are also examples of a broader category of aquatic habitat called floodplains (Welcomme 1979). Floodplains are those areas associated with a river which are affected by seasonal overspill from the main channel (Welcomme 1979). A seasonal cycle of flood and drought is therefore imposed on much of the floodplain area (Welcomme 1979). Channels connecting with the river and low lying depressions which contain a core of permanent water throughout the year are considered to be an integral part of the floodplain (Welcomme 1979).

Deltas are frequently included in the literature under the heading of wetlands. The term wetland has been defined by Peters et. al. (1978) to mean an area lying between the boundary of hydrophytic plants or hydric soils on one side and a water depth of 2m below low water level on the other.

The term marsh, in this report, is of limited applicability to the Netley-Libau Marsh. A marsh is a tract of land often periodically inundated and treeless and usually characterised by grasses, cattails or other monocotyledons. Marsh habitat in the Netley-Libau Marsh area would probably be classified under the seasonal hydro-pulse (lotic) and variable/seasonal hydro-pulse (lentic or riverine) categories of Gosselink and Turner (1978). The term marsh however refers to a specific habitat component of the total Netley-Libau area since open water areas in the form of lakes and streams occur in addition to marshy areas.

Irregardless of the terminology used, deltas, floodplains, wetlands and marshes are examples of ecosystems which are often highly significant as a result of high biological productivity. These ecosystems are generally net producers since primary production exceeds consumption (Gosselink and Turner 1978). Odum (1971) stated that such systems are pulse stabilized at an early relatively fertile successional stage by seasonal and daily water level fluctuations. Open system wetlands (e.g. riverine marshes) have been placed among the most productive ecosystems of the world (Westlake 1963; Leith 1975). There are typically three reasons given for this high productivity (Odum 1971):

1. these areas are able to retain and rapidly recycle nutrients
2. these areas often contain the three major production groups namely macrophytes, benthic microphytes and phytoplankton
3. these areas have hydrologic regimes (esp. tidal areas) which provide an energy subsidy that reduces the cost of maintenance. The back and forth movement of water does "free work" by removing wastes and transporting food and nutrients

For fisheries, the high trophic status of these ecosystems has been expressed as an empirical relationship between mean depth and fish biomass and yield. Deltas, floodplains, wetlands and marshes are typically shallow water zones. Rapid nutrient recycling, associated with shallow water zones, not only results in a higher level of primary productivity, but also in greater zooplankton abundance and biomass, greater macrobenthos diversity, biomass and turnover rates and ultim-

ately greater fish abundance and biomass (Hanson and Leggett 1982). For these reasons fish productivity approaches a maximum with decreasing depth. The fish productivity of lakes of similar nutrient status is therefore related directly to the extensiveness of the littoral zone (Hanson and Leggett 1982). Welcomme (1979) stated that perennial flood rivers support some of the richest inland fisheries and that fisheries production in such rivers is proportional to the extensiveness of their floodplains. Peters et. al. (1978) state that all freshwater fishing should be considered as dependent on wetlands because:

1. Many species either feed in wetlands or on wetland produced food
2. Many species utilize wetlands as a nursery area
3. Almost all important fishes spawn in the aquatic portion of the wetland zone

The way in which fish populations use floodplain areas has been summarized by Welcomme (1979). Typical floodplain have a seasonal cycle of expansion and contraction associated with variations in flooding levels. The floodplain cycle imposes a seasonality on fish populations. As floods recede most fish species leave the floodplain as it contracts. Others become trapped in isolated areas. Species which do not leave the floodplain are often adapted to survive the adverse conditions at this time of the flood cycle. During flooding an ordered sequence of species migrates onto the floodplain as it expands. Species which spawn on the floodplain often synchronize their migration with the beginnings of the seasonal flood. Other early entrants may be the condition tolerant

species which stayed in the remaining waters of the floodplain. The flood portion of the cycle is associated with a rapid increase in food organisms and wide dispersal of fish over an extensive biotope which favours intensive feeding. From these observations, Welcomme developed the principle that a floodplain should be considered, not in isolation, but as an integral component of the larger river system. This is in keeping with Odum's (1971) principle that practical management must consider the whole drainage basin (watershed unit) not just a particular body of water, as the minimum ecosystem unit.

Welcomme (1979) identified four main stages which typically occur in floodplain modification with three cutting points marking transitions between them. Typically, floodplain development is initiated by agricultural use which increases population size and fishing pressure and initiates some drainage and regularization of the plain. Secondary development occurs with the installation of flood control structures which begin to modify the hydrologic regime and restrict the area available to fishes. Complete modification often results from upstream damming which eliminates flooding and leaves only a small amount of water in the system.

The fish community of a floodplain changes as successive floodplain modifications take place in a manner similar to the "fishing up" process. Initially, fishing pressure results in higher proportions of smaller fishes as the larger individuals are cropped (Welcomme 1979). As the hydraulic regime becomes more stabilized larger species tend to disappear and may be replaced by species which were previously minority members of the community (Welcomme 1979). Eventually number of species

in catch, catch per unit of fishing intensity, biomass, total catch, and biological fish production can be expected to decline (Welcomme 1979). As these changes occur, the introduction of exotic species and intensive aquaculture are often used to try and compensate for lost species and lessened production by riverine species (Welcomme 1979).

These fish community changes may take place due to the potential of wetland habitats (e.g. lakeshore lagoons) for exerting a continuous extinction pressure on colonizing fish species (Mahon and Balon 1977). Fishes usually invade wetland habitat at any time that it becomes accessible (e.g. during high water levels due to storms) (Mahon and Balon 1977). Temperate wetland habitats, however, are extremely difficult for fishes to colonize since their shallow depth may result in winterkill. When wetlands become isolated naturally, general and selective mortalities are generated by winterkill, predation, competition and other physical conditions (e.g. high summer temperatures) (Mahon and Balon 1977). Species specific ecological characteristics such as the ability to survive extreme conditions, territoriality and nesting/guarding reproductive styles then become most advantageous (Mahon and Balon 1977). Species which do not possess such adaptations may suffer rapid extinction (Mahon and Balon 1977). Areas that are not sufficiently large, sufficiently deep or which are not occassionally accessible may become devoid of fish life (Mahon and Balon 1977). Intuitively, it seems that these mechanisms must also operate in floodplain areas where isolation is caused by extensive flood control measures or lowered water levels resulting from upstream damming.

Haedrich (1975) proposed a simplistic model relating shallow water fish community structure to environmental quality (Horn 1980). When environmental stress is low the fish community should have a relatively high total diversity, as measured by a diversity index, and a wide seasonal range in similarity, as measured by a similarity index. When environmental stress is high the fish community should have low total diversity and high between season similarity. Horn (1980) evaluated the model for fish communities of unaltered and moderately altered (by pollution) shallow water marine environments in California. The Shannon-Weiner diversity index (H´) was found to be greater than 1.00 for relatively unaltered areas and less than 1.00 for moderately altered areas. The Whittaker and Fairbanks's index of similarity (PS) range for unaltered areas was 24-62%. Moderately altered areas showed a PS range not originally recognized by Haedrich. They had a wide range in PS = 2-96% caused by the absolute replacement, seasonally, of one species by another.

Priegel (1970) documented the importance of riverine marshes as primary spawning and nursery areas for Lake Winnebago walleyes *(Stizostedion vitreum)*. He cited level ditching, dyking, and pond construction within the marshes as major causes which destroyed spawning and nursery grounds. These developments changed flows or completely eliminated current over the marshes which were required for the attraction of fish, the aeration of eggs and the flushing of fry from the marshes. In Canada, the Peace-Athabasca Delta project group (1972) recommended water control to alleviate low water regimes caused by the

upstream W.A.C. Bennett Dam. The project group stressed the requirement for the inclusion in water level controls of provisions for free access of fish to and from important areas in the delta in order to protect the fish stocks of Lake Athabasca.

Welcomme's (1979) most striking examples of the effect of development on fisheries associated a 67% loss of floodplain area in the Missouri River between 1879 and 1967 with a steady decline in catch from 680t in 1894 to 122t in 1963 (an 82% reduction in catch). The decline in catch was mainly due to fish habitat losses following the construction of reservoirs, channel modifications by dyking of the main and side channels, and the blocking of backwaters. Francis et. al.(1979) and Paloheimo and Regier (1982) cited improper wetland management as well as the dyking and draining of wetlands in a list of 18 human stresses which have acted synergistically on the ecosystem to produce declines in the value of Canada's Great Lakes fisheries.

Francis et. al. (1979) listed Great Lakes wetland stresses as:

1. loss of hydrologic connectivity between coastal habitats
2. reduced interchange of littoral and wetland water masses
3. reduction in allochthonous sediment trapping and nutrient uptake capability
4. interruption of detrital exportation into the Great Lakes

Among other changes these manifestations resulted in loss of fish populations except for tolerant, warmwater species within

dyked wetlands as well as the reduction in multiple use and species diversity of dyked areas, less total spawning and nursery habitat available to wetland dependent fish stocks and the reduction in the quality and availability of invertebrates to forage minnows and other Great Lakes fish (Francis et. al. 1979).

Welcomme (1979) recommended that fisheries planning for floodplain rivers give top priority to assuring that lateral expansion zones are kept free from engineering works such as levees, polders and embankments which have been shown to interfere with the natural pattern of flooding. On the Great Lakes a need has been identified for support data to convince public wetland managers that open water wetlands are more productive in the long run, than dyked wetlands (Francis et. al. 1979). The rehabilitation of Great Lakes wetlands (Francis et. al. 1979) has stressed the need to:

1. remove earthern dykes to allow wetlands to shift laterally during lake level fluctuations
2. modify breakwaters, jetties, bridges and rip-rap erosion control structures to allow hydraulic connectivity
3. redesign artificial drainage canals to facilitate dispersal of runoff water and suspended solids along the landward margins of wetlands
4. implement area wide water quality management controls to reduce sediment and nutrient loading of wetlands from developed terrestrial areas
5. regulate future construction of canals across coastal wetlands
6. create artificial wetlands along extensively developed coastlines

Both Odum (1971) and Welcomme (1979) recommend a management approach for floodplain areas oriented toward preservation of the natural system. Careful fish husbandry can be used to more fully realize maximum use of the potential productivity of natural systems according to Welcomme (1979). Methods of fish husbandry and aquaculture are recommended for areas in which productivity has decreased due to slight or extensive floodplain modification (Welcomme 1979). Existing methods of husbandry and aquaculture are crude and often lack rationalization however, and the development of appropriate technology is often lacking (Welcomme 1979). As Odum (1971) has pointed out use of these methods represents an energy input into the system in terms of an initial capital outlay for research and development as well as subsequent maintenance costs. In cases where husbandry and aquaculture must be used to replace values which were originally a "free gift of nature" the cost to the taxpayer is doubled (Odum 1971). The cost of constructing a poorly planned development which subsequently destroys a "free gift of nature" (eg. spawning, nursery and feeding grounds) will become a double cost when the cost of replacement or maintenance (eg. fish husbandry and aquaculture) is taken into account (Odum 1971).

METHODS AND MATERIALS

The Wildlife Branch request for a resource description of Netley-Libau Marsh coincided with existing fisheries surveys in the Netley-Libau area. These surveys were expanded and modified to fulfill the more general objectives directed by the Wildlife Branch request.

PHYSICOCHEMICAL FEATURES

Physical - To assess the physical state of Netley-Libau Marsh a qualitative comparison was made between general physical features of the marsh during the 1980-1981 surveys and a map drawn from 1965 aerial photograpy and ground surveys conducted between 1954 and 1958[1].

Seasonal fish habitat availability was evaluated by comparing water depth and ice thickness measurements (Appendix A). Approximate mean water depth was determined from spot depth measurements using a sounding line graduated in meters. The sounding line could be used to measure ice thickness since the elongate sounding lead was mounted horizontally to catch the bottom edge of the ice surface.

Thermal fish habitat suitability at Netley-Libau Marsh was determined by describing the water temperature regime for comparison with Hokanson's (1977) temperature classification for temperate-climate freshwater fish. Surface water temperatures were obtained from oxygen

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[1]The Red River Delta, Dept. Energy Mines and Resources Map 62/I7 ed. MCE Series A743; 1:50000 scale

testing sites and most fish collection sites (Appendix A). The presence of thermal stratification was tested using a standard paired t-test on surface and bottom water temperature measurements. The water temperature regime was described by creating a composite water temperature record of water temperatures combined into weekly intervals regardless of sampling site. Water temperatures were measured with an electronic thermometer.

Chemical - The water chemistry of Netley-Libau Marsh was characterized by determining ionic ratios according to the classification of Barica (1975). Total dissolved solids (TDS) were determined for comparison with the classification of Northcote and Larkin (1963). Hydrogen ion (pH) and calcium concentrations were determined for comparison with the trophic state classification of Reid (1961). Additional trophic state indicators were generated by calculating potential fish yield and standing crop from total phosphorus (TP) and mean summer chlorophyll concentration (CHL_s) according to the models of Hanson and Leggett (1982) and Oglesby (1977). Hanson and Leggett's equations were used as published. Oglesby's yield equation was recalculated from his raw data to provide prediction intervals for comparing estimates to Hanson and Leggett's model. Prediction interval calculations were made according to Snedecor and Cochran (1967). Samples for water chemistry analyses were collected in June, July and August 1981 from three marsh lakes (Appendix A). Four samples were obtained from each site and delivered for analyses within 24 h. With the exception of specific conductance all analyses were performed by the Technical Services laboratory of the Environmental Management Division

of Manitoba's Department of the Environment. Specific conductance was measured at the water's surface with a YSI electronic instrument.

To describe the oxygen regime, oxygen levels were measured for comparison with Davis's (1975) guideline of 47% saturation for onset of oxygen distress symptoms in mixed populations of freshwater fish. Oxygen concentrations were determined using the titrimetric method of Stainton et. al. (1977). All water samples were treated to fix oxygen content at the sampling site. Oxygen concentrations were measured as $mg.\ell^{-1}$ and converted to percent saturation using saturation levels corrected to sampling temperature and elevation. Measurements were initially made in January, February and March of 1981 (Appendix A). During this period water samples were collected directly into 300 ml B.O.D. bottles with as little agitation as possible. Substantial thawing of ice in late February and March due to unseasonably mild weather made a number of measurements unreliable, in our estimation, as a result of abiogenic supersaturation. A Kemmerer water bottle was used to collect all subsequent samples. Measurements were again made in June, July and August, 1981 (Appendix A). At that time most samples were obtained from midwater. The presence of a vertical oxygen gradient was tested using a paired t-test on a limited number of surface and bottom oxygen measurements.

THE FISH COMMUNITY

The Netley-Libau Marsh fish community was described from fish collections made with gillnets, fyke nets and rotenone. Fish collections were used to estimate fish community dynamics in terms of species number, similarity, diversity and abundance (Horn, 1980). Additional description was provided by classifying the fish community according to temperature requirements, spawning requirements, known movement patterns and predominant feeding modes. In keeping with standard fisheries survey practice in Manitoba the population dynamics of three abundant species were detailed.

Representative fish were keyed to species according to Scott and Crossman (1973) to compile a species list.

Fish community similarity and species composition groupings were described primarily from an experimental gillnetting survey carried out in 1981. Three standard gillnet gangs were fished per month for the approximate period May through August at Upper Devil, Lower Devil and Beaconia lakes (Appendix A). An additional standard gang was fished at Lower Devil Lake in October 1981. Each net set was 24 h in duration. The standard gang was composed of six gillnets each 22.9m long and 1.8m deep. Mesh sizes were randomized as 3.8 cm, 9.5 cm, 5.1 cm, 10.8 cm, 7.6 cm and 12.7 cm in order. At each net lift fish were counted and weighed by species. Detailed analyses were limited to species compositions from numbers of fish captured. Species compositions were compared by season and area using the simple agglomerative information analysis of Mountford (1962) on Whittaker and Fairbanks similarity indices (PS) (Horn 1980) calculated for all paired species composition combinations.

Additional non-systematic gillnetting results from 1980 and 1981 were pooled with appropriate species composition groupings from information analysis to more completely describe fish community similarity. There were three additional sets of data. Eight standard gang sets had been made between August 15 and October 23, 1980 (Appendix A). Two gillnets sets had been made in mid March 1981 (Appendix A). Nets were the smaller mesh sizes of the standard gang that could be effectively fished in the limited space available under ice cover in two marsh creeks. The 3.8, 5.1, 7.6 and 9.5 cm meshes were used at a marsh channel near Pruden Bay. The 3.8, 5.1 and 7.6 cm meshes were used at Devils Creek. Winter net sets were 72 h in duration. A 7.6 cm mesh size gillnet was fished from April 10 to May 3, 1981 in the Devils Creek - Upper Devil Lake area (Appendix A). The 9.5 and 10.8 cm mesh sizes were included in two sets during this period.

Fish community diversity was described by calculating the Shannon-Weiner diversity index H´ for the species composition groupings of pooled gillnetting results.

Dominant species were identified by inspecting species composition groupings for species contributing the most to 80% of total individuals captured in pooled gillnet results.

Detailed species composition data for small fishes were not collected. Additional non-systematic fishing with fyke nets and rotenone however provided some observations of small, young-of-year and juvenile fishes. A Maine fyke net was fished from April 18 to May 9, 1980 at Devils Creek (Appendix A). The net was again used from August

14 to September 4, 1980 in four Netley-Libau Marsh lakes. The net was made from 6.3mm oval nylon mesh mounted on 1.9 cm aluminum tube frames. The net entrance was 1.2m x 1.2m tapered to 0.8m x 0.8m. The net had a 0.6m trail, 7.6m wings and 30.5m lead. The lead was used as an extension of one wing for all creek fishing. All summer sets were made using the lead in the traditional manner. In one instance rotenone was used to provide additional small fish information. The poison set took place on September 5, 1980 (Appendix A).

Fish abundance was measured as catch per unit of effort (CUE). Units were defined as total fish caught per standard gillnet gang per 24 h. Total fish abundance was defined from standard gillnet catches as the untransformed 95% confidence interval on mean CUE. CUE values for dominant species were determined from the systematic gillnet survey. CUE data were grouped into 3 areas with four time periods. Untransformed data were tested for variance heterogeneity using a maximum variance ratio test (Sokal and Rohlf 1969). Two way model I analyses of variance (ANOVAS) were used to test the variability of catches in space and time (Sokal and Rohlf 1969).

Thermal classification of the fish community was based on Hokanson (1977).

Spawning requirements in terms of spawning season, spawning temperature, spawning substrate and reproductive strategy were determined from Hokanson (1977), MacLean and Magnuson (1977) and Balon (1975).

Generalized movement patterns of dominant Netley-Libau Marsh species were established from Scott and Crossman (1973) with noted exceptions. Additional movement data were available from limited walleye

(Stizostedion vitreum) tagging at Netley-Libau Marsh in the spring of 1980. Yellow numbered floy tags were inserted between the interneural bones at the posterior margin of the dorsal fin. Certificates were offered for angler tag returns and a $2.00 reward for returns by commercial fishermen.

Classification of the fish community by predominant feeding mode was based on MacLean and Magnusson (1977). Field examination of 115 sauger and 216 northern pike stomachs provided some actual diet data.

The population dynamics of sauger, northern pike and goldeye were described. Lengths were measured as fork length to the nearest 2mm. Individuals were also weighed to the nearest 20 g. Sauger were aged from a scale taken above the lateral line near the posterior margin of the dorsal fin and by otoliths. Goldeye were aged from scales taken in the same way as samples from sauger. Goldeye were also aged using pelvic fin rays. Northern pike were aged using the cleithral bone. The sex and state of maturity of sauger and northern pike were determined. All fish showing milt or eggs were classsified as mature. Growth in length and weight, growth in length with age, survival rates and maturity rates were calculated according to Ricker (1975) and Lysack (1980, 1981).

ASSOCIATED FISHERIES

Detailed surveys of fishing activity were not carried out. Some qualitative observations however were available on fishing activity within Netley-Libau Marsh as a result of the presence of survey crews in the area. Additional information on Netley-Libau Marsh fishing and

fishing in the Red River and Lake Winnipeg was obtained from internal reports and discussions with fisheries management personnel.

RESULTS

PHYSICOCHEMICAL FEATURES

Physical - In 1980/81 the Netley-Libau Marsh was similar, at least superficially, to the description provided by the Lake Winnipeg Marshes Working Group (1977). Changes to the current topographical map as a result of the 1975 regulation of Lake Winnipeg appeared to be minimal. Dykes to prevent flooding of adjacent agricultural land were noted at Goldeye and Upper Devil lakes but the total amount of dyking is not extensive. Extensive channelization was evident in the upstream reaches of Devils Creek between Tyndall, Manitoba and Highway 59. Extensive sections of the creek banks have also been denuded of vegetation. Breaching of previously continuous levees was noted between Netley Lake and the Red River and at Ramsay Lake. The breach at Netley Lake has a long standing history which is not attributable to Lake Winnipeg regulation (Unies Ltd. 1972). The origin of the breach at Ramsay Lake is unknown. Goldeye Lake is a Ducks Unlimited project. Works were constructed in 1959 and consist of peripheral dyking and a fixed crest weir across Goldeye Creek. An open culvert provides free water flow into and out of Goldeye Lake. When water levels are high, water also flows across the weir.

Abnormal weather conditions occurred in both years of study. The spring of 1980 was exceptionally mild. Spring breakup of tributaries such as Devils Creek took place in the first week of April. By late April, peak flows had passed. Unusually mild conditions also occurred in late winter, 1980/81. The Red River, at Selkirk, broke up toward the last week in March, 1981 (R. Tees, pers. comm.[1]). The peak on April 4, 1981 was one of the lowest peaks on record (Manitoba Water Resource Branch records). Tributaries such as Devils Creek began to flow in early April but flow rates were minimal. Spring break up was atypical in that ice melted gradually rather than breaking up and being flushed downstream. Marsh lakes were ice free by April 21, 1981. Stream flow information for Devils Creek corroborates these observations. Flow rates and total discharge were below average in both years (Fig. 3, Appendix B). Ice formation was beginning at lake edges by October 23 in 1980 and by October 28 in 1981.

Marsh lakes were relatively uniform in depth which typically did not exceed 1m over the majority of each basin. Marsh channels were deeper with a range of 1 to 4m or more. Twenty marsh lake measurements had a mean total depth (ice plus water) of 0.76m, a standard deviation of 0.30m and a range of 0.30-1.75m (total range = 1.45m) (Appendix C). Twenty-nine marsh channel measurements had a mean of 1.77m, standard deviation of 1.07m and range of 0.88-4.00m (total range = 3.20m) (Appendix C). Depth measurements for gillnetting stations at Upper

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[1]Conservation Officer, Selkirk, Manitoba. Dept. Nat. Resources.

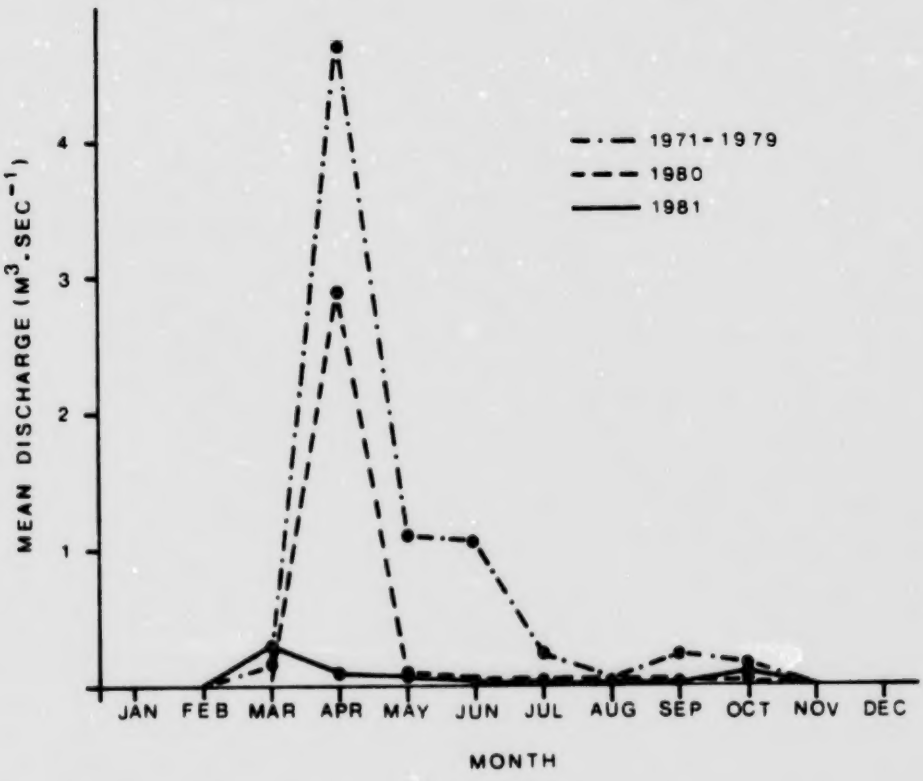

Fig. 3. Mean monthly flow rate of Devils Creek near Libau.

Devil, Lower Devil and Beaconia lakes during the open water season of 1981 showed mean depths of 1.17, 1.06 and 0.99m respectively (Appendix C). Gillnetting stations, however, were located at the deepest portions of these lakes. The northern two thirds of Upper Devil Lake plus the lake's eastern bay had depths on the order of 0.3m. The majority of Lower Devil Lake was about 0.3-0.5m deep. Beaconia Lake had an extensive shallow area 0.1-0.2m deep with a deeper area in the western third of the lake 0.6-1.0m deep. Winter ice thickness had a mean of 0.85m, standard deviation of 0.21m and range of 0.26-1.63m for 32 sites at which both ice and water occurred (Appendix C). Marsh lakes were completely or nearly frozen to the bottom during winter (Appendix C). Although not quantified, water levels during the open water season varied markedly with wind setups on Lake Winnipeg.

Water temperature ranged from a low of $\leq 0^{\circ}C$ in areas frozen to the bottom during winter and during cold "snaps" in spring to a high of $24^{\circ}C$ during July and August (Fig. 4, Appendix C). April 1980 water temperatures were higher than April 1981 water temperatures. Surface and bottom water temperature measurements from Netley-Libau Marsh lakes (total depth at sampling sites $\sim$ 1.0m) were not significantly different at the 5% probability level (Appendix C).

Chemical - Predominant anion ratios were 0.98, 0.64 and 1.30 respectively for Upper Devil, Lower Devil and Beaconia lakes (Appendices D, E). Predominant cation ratios were 0.57, 0.53 and 0.80. Total dissolved solids were 215-500 $mg.\ell^{-1}$ (Appendix D). Mean pH ranged between 8.8 and 9.0 (Appendix D). Mean calcium concentration ranged between 37 and 51

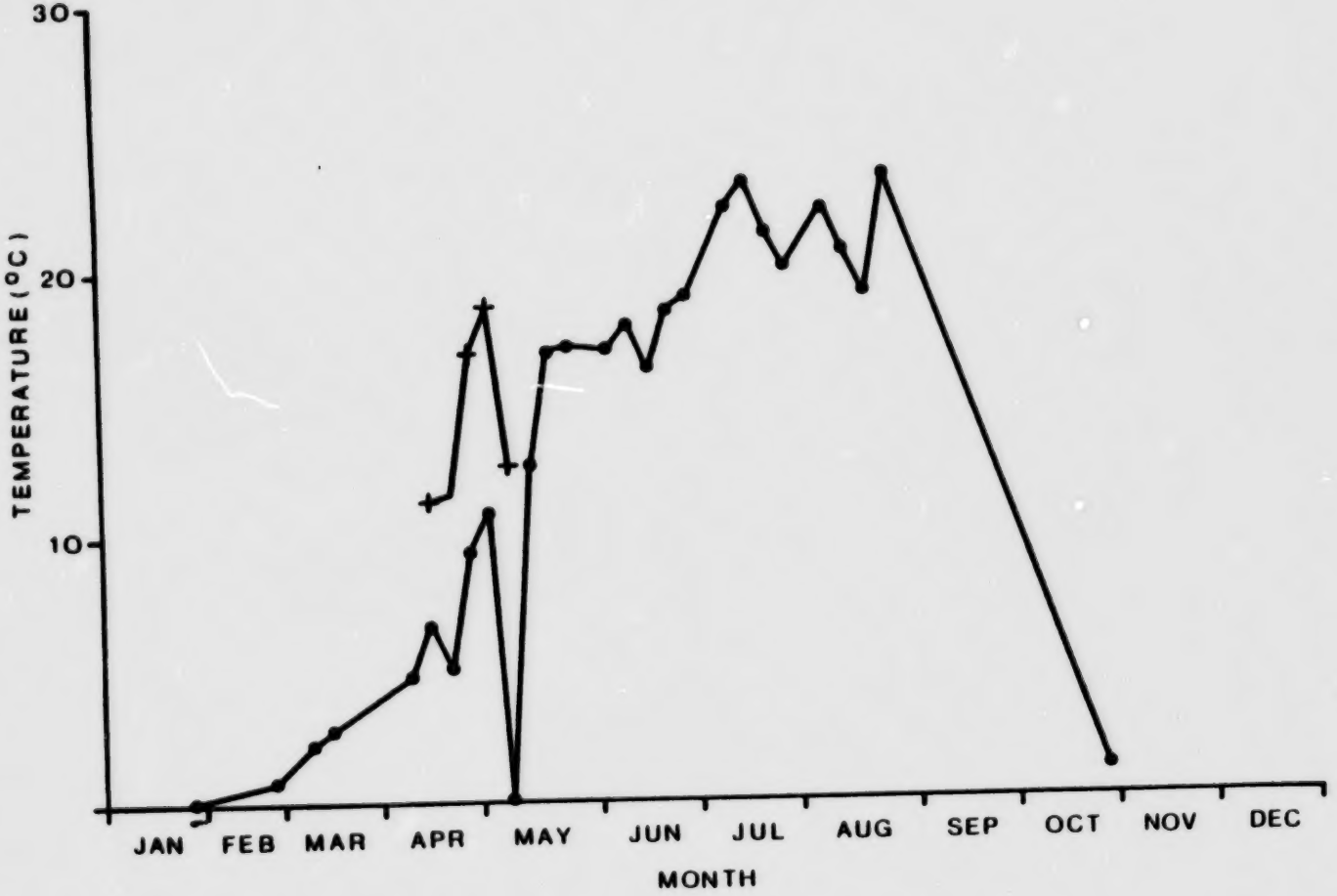

Fig. 4. Composite water temperature record. Crosses represent 1980 temperature observations. Dots represent 1981 temperatures.

$mg.\ell^{-1}$ (Appendix D). Theoretical fish standing crops (PFC) and potential yields (PFY) calculated from mean total phosphorus concentrations substituted into Hanson and Leggett's equations give values of PFC = 279-384 $kg.ha^{-1}$ and PFY = 17-27 $kg.ha^{-1}.yr^{-1}$ for the three tested Netley-Libau Marsh lakes (Table 1). Theoretical fish yields from summer chlorophyll concentrations substituted into Oglesby's relationship were 8.49-24.58 $kg.ha^{-1}.yr^{-1}$ for the three tested Netley-Libau Marsh lakes (Table 1). Ninety-five percent confidence intervals on fish yield from chlorophyll encompass field yield values predicted from total phosphorus.

Winter oxygen testing includes 37 measurements ranging from <0.7-244.0% of saturation (Appendix C). The mean dissolved oxygen concentration was 104.78% of saturation. These measurements were most indicative of thawing conditions in the marsh during the sampling period. Two stations (Goldeye Creek Nos. 2,3) demonstrate that the seasonal oxygen minimum occurred prior to the time that most sampling took place. These stations showed an average rise in oxygen concentration of 22.5% between January 28 and February 25, 1981 (Appendix C). The majority of winter oxygen measurements (86%) were made between late February and mid-March. A "corrected" data set including only measurements less than saturation or measurements from samples taken with a Kemmerer sampler gives a mean of 41.49% and a range of <0.7-138%. The most extensive oxygen testing data (Goldeye Lake, Goldeye Creek) indicated an oxygen gradient between frozen marsh areas and connecting waters (Fig. 5). Oxygen concentration increased with total depth and proximity to deeper water bodies such as the Red River.

Table 1. Theoretical fish standing crop yield for Netley-Libau Marsh and Lake Winnipeg.

Area	Total phosphorus model			Chlorophyll model	
	concentrations $\mu g.\ell^{-1}$	standing crop $kg.ha^{-1}$ [1]	yield $kg.ha^{-1}.yr^{-1}$ [2]	concentration $mg.m^{-3}$	yield 95% prediction interval $kg.ha^{-1}.yr^{-1}$ [3]
Upper Devil Lake	360	383.59	26.71	76.2	3.60<19.50<106.68
Lower Devil Lake	290	329.14	21.76	92.6	4.42<24.58<136.71
Beaconia Lake	230	279.32	17.35	37.8	1.63 <8.49 <44.21

[1] $\log_{10}$ FC =0.7081l $\log_{10}$ TP+0.774, where: FC = fish standing crop in $kg.ha^{-1}$ and TP = mean eplimnetic total phosphorus in $\mu g.\ell^{-1}$ (Hanson and Leggett, 1982)

[2] FY+0.072 TP +0.792, where FY = fish yield in $kg.ha^{-1}$ and TP = mean epilimnetic total phosphorus in $\mu g.\ell^{-1}$ (Hanson and Leggett, 1982)

[3] $\log_{10}$ Y=-1.92+1.17 $\log_{10}$ CHL_s, where Y_f is fish yield in g dry $wt.m^{-2}yr^{-1}$ and CHL_s is the mean chlorophyll + pheaopigment concentration in the upper 10m of the water column, June-August expressed as $mg.m^{-3}$.

During the open water season the mean dissolved oxygen level was 112% of saturation for 17 samples from 3 marsh lakes (Appendix C). Open water oxygen levels ranged between 85 and 163% (Appendix C). Surface open water oxygen concentrations from Netley-Libau Marsh lakes were significantly higher at the 5% probability level than oxygen concentrations at the bottom (total depth at sampling site ∿ 1.0m) (Appendix C).

THE FISH COMMUNITY

Fish community dynamics - Twenty-five species of fish were identified from the combined 1980-81 results of fyke netting, gillnetting and rotenone sampling at Netley-Libau Marsh (Table 2). Individual species of suckers *(Catostomidae)*, shiners *(Cyprinidae)* and bullheads *(Ictaluridae)* were identified and appear in the species list but in most samples the individual species were grouped.

The composition of the fish community varied seasonally. Spatial differences in species composition also occurred but were overshadowed by seasonal effects. Information analysis of species composition comparisons for the three lakes in the systematic gillnetting survey indicated a major division in species composition giving distinct early (May-June) and late (July-August) species compositions (Fig. 6). Inclusion of an October net set at Lower Devil Lake showed a third distinct species composition during the fall (Fig. 6). Information analysis on early and late species composition comparisons of the three tested lakes indicated that season fished was more important than area fished since

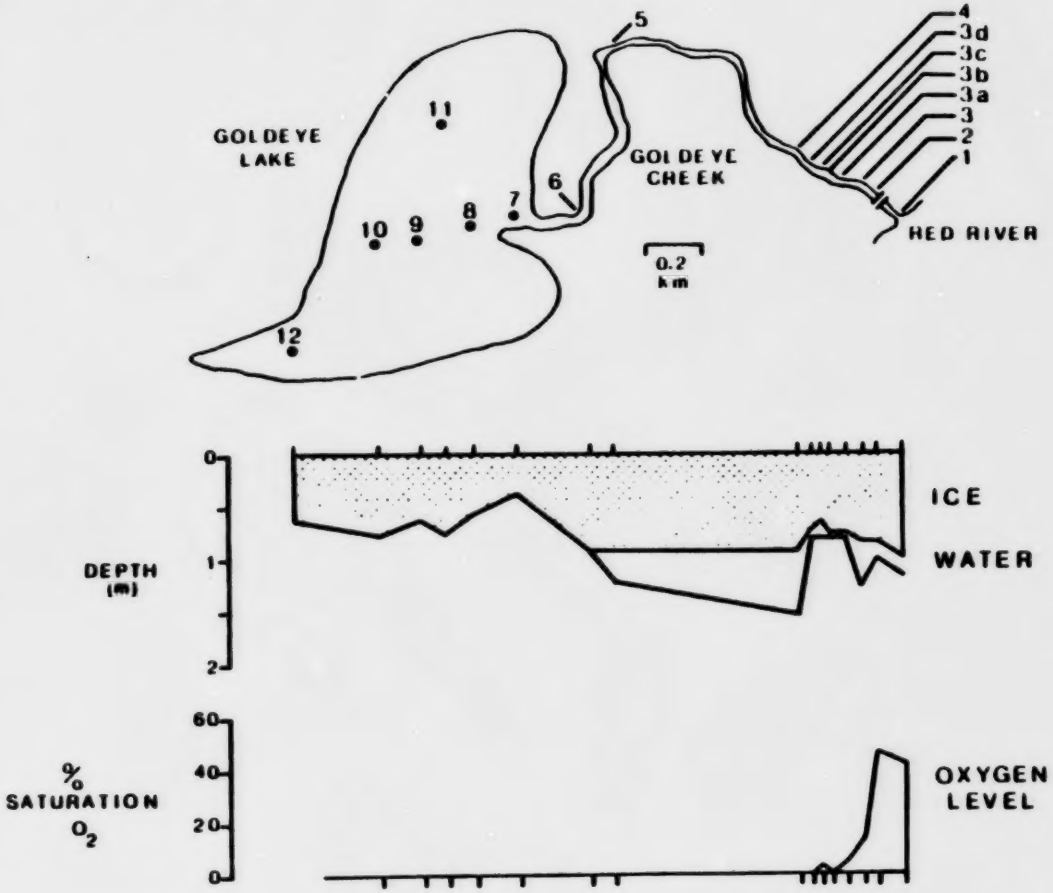

Fig. 5. Sampling sites, ice thickness, water depth, and oxygen levels in Goldeye Lake and Goldeye Creek, Netley-Libau Marsh, winter 1980-1981.

Table 2 . Common and scientific names of fishes captured in the Netley-Libau Marsh, 1980-1981.

Generic and specific name	Common name
Aplodinotus grunniens	freshwater drum
Hiodon alosoides	goldeye
Hiodon tergisus	mooneye
Lota lota	burbot
Coregonus artedii	cisco
Stizostedion canadense	sauger
Stizostedion vitreum	walleye
Catostomus commersoni	white sucker
Moxostoma anisurum	silver redhorse
Coregonus clupeaformis	whitefish
Percopsis omiscomaycus	trout perch
Perca flavescens	yellow perch
Morone chrysops	white bass
Cyprinus carpio	carp
Esox lucius	northern pike
Ictiobus cyprinellus	bigmouth buffalo
Carpoides cyprinus	quillback
Notropis hudsonius	spottail shiner
Notropis atherinoides	emerald shiner
Ambloplites rupestris	rock bass
Pomoxis nigromaculatus	black crappie
Ictalurus nebulosus	brown bullhead
Ictalurus punctatus	channel catfish
Noturus gyrinus	tadpole madtom
Ichthyomyzon castaneus	chestnut lamprey

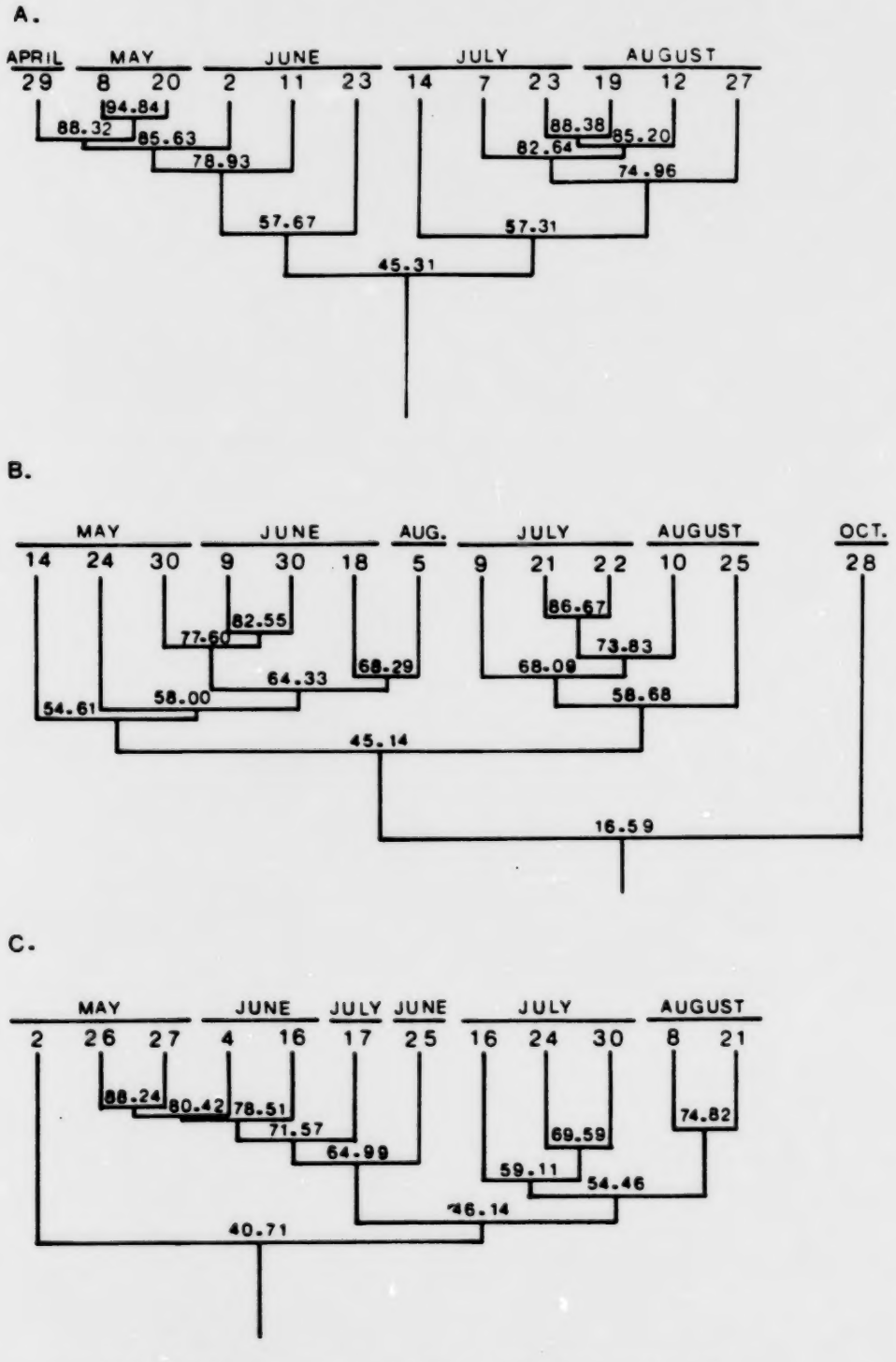

Fig. 6. Information analysis using similarity index of three marsh lagoons sampled in 1981 with gillnets. A. Upper Devil, B. Lower Devil, C. Beaconia.

species compositions were combined according to early and late periods rather than by areas (Fig. 7).

Inspection of non-systematic gillnetting results showed that all species compositions between mid-September and mid-March were highly similar. Also gillnetting results from August of 1980 were similar to August of 1981. Based on similarity by inspection and by the results from information analysis a composite representation of seasonal species composition was constructed (Table 3). The composite was constructed by combining all gillnet results regardless of mesh size, year, or area fished into month fished and subsequently into season fished (Appendix F). Overall, similarity ranged from <20% (winter month vs summer month comparison) to >80% (winter month vs winter month comparison). In general there was high similarity in the fish community during fall and winter (PS$\sim$87%) with intermediate similarity (PS$\sim$41-45%) during the open water season, resulting in three distinct fish communities (i.e. fall-winter, spring, summer).

Shannon-Weiner Diversity Indices (H′) calculated from the composite seasonal species composition had a range of 0.51-1.95 (Fig. 8). Diversity was lowest in March (H′ = 0.51) and was maximum in August (H′ = 1.95). Average annual diversity at Netley-Libau Marsh calculated as the mean of monthly diversity values was H′$\sim$ 1.13 assuming an unchanging diversity of 0.60 (mean of October and March values) between October and March.

Gillnetting results indicated that seven types of fish, in different seasonal combinations, dominated the Netley-Libau Marsh fish

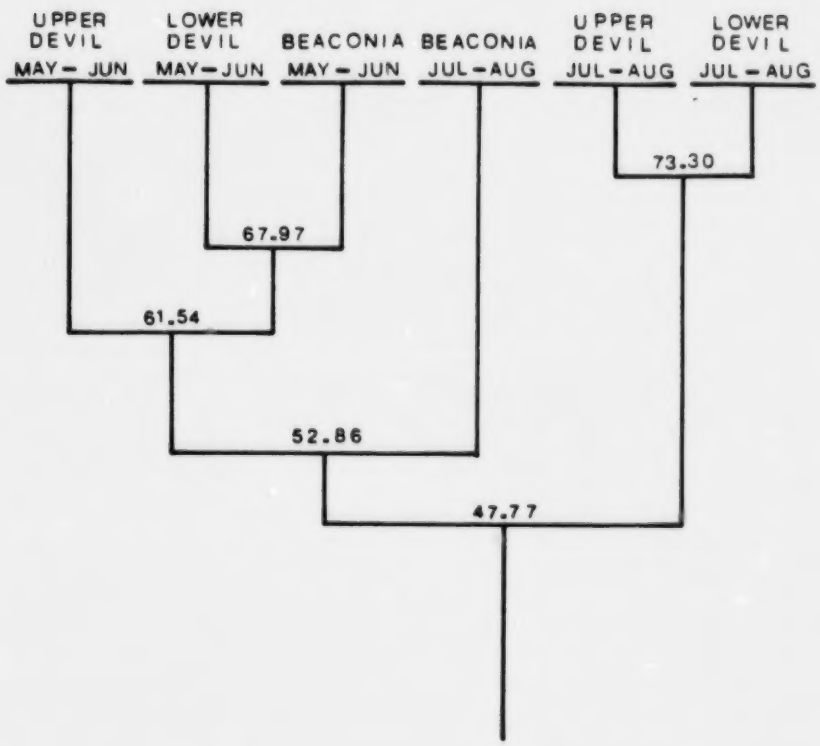

Fig. 7. Information analysis for comparisons of spatial variation in species composition for three Netley-Libau Marsh lagoons. Mountford's (1962) procedure was used on the % similarity index of Whittaker and Fairbanks (1958).

Table 3. Seasonal community structure of fishes at Netley-Libau Marsh, 1980-1981. Data are derived from combined gillnetting, 1980-1981. Nets were standard gangs with noted exceptions.

	% number of fish caught[1]							
	winter	spring			summer		fall	
	March[2]	April[3]	May[4]	June	July	August	September	October
freshwater drum			2.40	6.77	10.76	6.01	1.96	
goldeye	1.56		2.95	4.65	31.70	20.51		
mooneye				0.21	0.70			
sauger			3.31	13.45	13.60	20.79	23.53	
walleye		0.67	1.59	1.35	0.05	0.52		
sucker	3.52	4.80	5.09	0.47	0.29	2.79		
yellow perch	2.35	15.13	8.97	2.55	10.74	11.49	11.76	12.66
white bass			0.13		0.93	0.22		
carp		0.62	15.87	11.01	3.48	5.38	6.62	
northern pike	80.86	44.67	18.64	8.20	7.20	3.26	49.50	84.78
quillback		0.24	1.83	1.31	0.20	2.13		
rock bass				0.16	0.15	0.08		
bullhead	11.71	33.87	38.63	49.12	19.45	26.29	6.63	1.28
channel catfish			0.25	0.75	0.75	0.40		
cisco			0.04					
whitefish								1.28
bigmouth buffalo			0.30			0.13		
Number of gillnet sets	2	9	11	9	10	13	2	2

[1] data are mean values of the % proportion of fish in a given species in each net set.

[2] based on: 3.8, 5.1, 7.6, 9.5 cm mesh sizes combined (1 set) and 3.8, 5.1, 7.6 cm mesh sizes combined (1 set).

[3] based on: 8 sets of 7.6 cm mesh size and 1 set of standard gang meshes.

[4] based on: 3 sets of 7.6, 9.5, 10.8 cm mesh sizes combined and 8 sets of standard gang meshes.

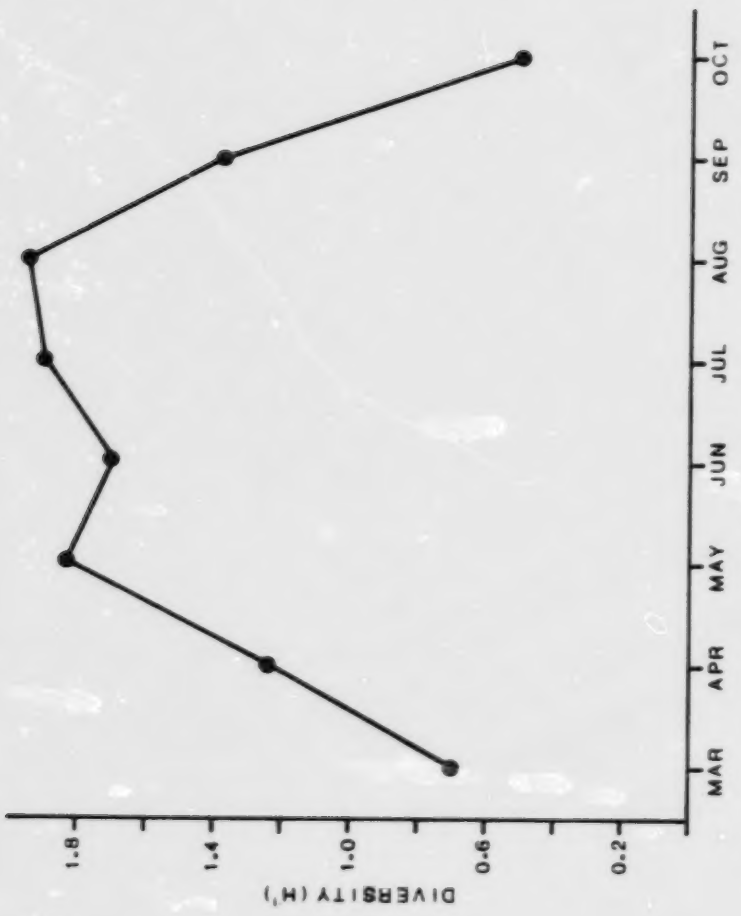

Fig. 8. Seasonal variations in the Shannon-Weiner Diversity Index for fish species composition at Netley-Libau Marsh, 1980-1981.

community (Table 3). The fall-winter community was dominated by northern pike. In spring, bullhead, northern pike, yellow perch and carp dominated. In summer, goldeye, bullhead, sauger, yellow perch and freshwater drum dominated.

From the combined results of fyke netting, gillnetting and rotenone, small fishes were dominated by juveniles and young-of-year fishes, most notably bullhead, carp and shiners (Table 4). Most dominant small fishes were also represented by adults in gillnetting results. Shiners, which were not vulnerable to gillnets, represent an addition to the seven dominant species identified from gillnetting. Shiners were the most abundant small adult size fish captured in fyke nets but their numbers in this gear were low (Table 4). It was apparent during fishing that shiner schools were using fyke nets as shelters but were not highly vulnerable to capture. The fyke net mesh size was too large to capture all but the largest shiners. Rotenone sampling showed that small size shiners were abundant at Netley-Libau Marsh (Table 4).

Total mean fish adundance was 108-159 fish.standard gang^{-1}. 24-h^{-1}. Untransformed CUE for dominant species showed heterogeneous variance for several species. A square root transformation was applied to the data based on Moyle and Lound's (1960) suggestion that catches of fish in nets may follow an approximate Poisson distribution. The transformed data showed homogeneous variances. CUE was significantly variable for all tested species with the exception of freshwater drum (CUE = 5.40) (Table 5). Freshwater drum catches were not significantly different in space or time. Sauger were most adundant in August when they reached

Table 4. Small fish, young-of-year and juvenile fishes captured at Netley-Libau Marsh, 1980-1981.

Common name	capture gear	Number of fish caught	Proportion of total caught %	typical size (mm)	Time of measurement
freshwater drum	fyke net[1]	2	0.02	70	August
freshwater drum	rotenone	-	<10.00	66	September
trout-perch	fyke net	12	0.10	71	April, August
trout-perch	rotenone	-	<10.00	-	September
yellow perch	fyke net	61	0.52	100	August
white bass	rotenone	-	<10.00	58	September
white bass	fyke net	15	0.13	66	August
carp	fyke net	2604	22.02	38	September
shiners	fyke net	61	0.52	75	August
shiners	rotenone	1000+	>90.00	35	September
bullhead	fyke net	8976	75.95	76	April, August
channel catfish	fyke net	1	0.01	53	April
rock bass	fyke net	1	0.01	95	April
black crappie	fyke net	79	0.67	69	August
tadpole madtom	fyke net	6	0.05	66	August
goldeye	rotenone	-	<10.00	112	September
goldeye	gillnets	2	2.38[2]	127	August

[1] Numbers of fish caught were corrected according to field notes on numbers captured and size distribution so that only small fishes appear in this table.

[2] 2.38% of total goldeye caught in 1980 gillnets.

Table 5. Results of Two-Way Model I ANOVA on transformed gillnet catches ($\sqrt{X + 0.05}$) of seven common Netley-Libau Marsh species, 1981.

Species	F - test values, degrees of freedom and significance		
	Months	Areas	Interaction
sauger	7.73 (3,24) *	20.96 (2,24) *	1.29 (6,24) n.s.
goldeye	33.48 (3,24) *	31.56 (2,24) *	6.39 (6,24) *
northern pike	23.40 (3,24) *	1.38 (2,24) n.s.	1.62 (6,24) n.s.
bullhead	4.48 (3,24) **	22.91 (2,24) *	2.37 (6,24) n.s.
carp	3.35 (3,24) **	0.84 (2,24) n.s.	1.21 (6,24) n.s.
perch	5.28 (3,24) *	0.11 (2,24) n.s.	0.89 (6,24) n.s.
drum	2.64 (3,24) n.s.	1.35 (2,24) n.s.	1.69 (6,24) n.s.

*indicates probabilities between 0.05 and 0.01

**indicates probabilities equal to or less than 0.01

n.s. indicates no significant difference

Table 6 . Mean catches, number of fish per 24 hr. of standard gang, of seven common marsh species[1].

Species	Area	Month				Area mean	Overall mean
		May	June	July	August		
sauger	Upper Devil	0.50	7.24	13.23	18.92	8.34	
	Lower Devil	9.61	32.33	21.10	58.33	27.66	10.66
	Beaconia	0.87	0.27	5.31	5.76	2.53	
	Month mean	2.68	9.30	12.38	23.12		
bullhead	Upper Devil	204.75	61.33	50.57	78.77	90.89	
	Lower Devil	41.13	35.01	9.41	21.33	25.08	37.65
	Beaconia	15.95	25.27	18.47	4.17	14.81	
	Month mean	68.03	39.19	23.35	27.02		
goldeye	Upper Devil	0.50	2.29	97.36	67.95	26.63	
	Lower Devil	7.39	10.47	73.27	43.32	27.93	15.48
	Beaconia	0.27	0.27	2.71	4.54	1.60	
	Month mean	1.94	3.32	45.17	32.14		
n. pike	Upper Devil	29.10	6.72	7.06	2.20	9.30	
	Lower Devil	21.99	6.45	3.14	2.52	7.10	7.57
	Beaconia	13.40	5.14	3.36	5.63	6.45	
	Month mean	21.00	6.09	4.37	3.31		
carp	Upper Devil	8.14	7.59	10.14	5.88	7.87	
	Lower Devil	9.97	4.97	3.32	3.97	5.31	6.55
	Beaconia	16.58	7.40	2.42	3.46	6.58	
	Month mean	11.31	6.60	4.83	4.38		

Table 6 (cont'd)

Species	Area	Month				Area mean	Overall mean
		May	June	July	August		
perch	Upper Devil	15.62	0.61	11.79	8.88	7.96	
	Lower Devil	3.88	0.70	15.88	17.97	7.81	8.36
	Beaconia	12.77	2.92	8.18	16.47	9.35	
	Month mean	10.07	1.27	11.75	14.14		
drum	Upper Devil	0.46	2.69	1.89	12.33	3.39	
	Lower Devil	7.51	7.11	4.87	8.83	7.01	5.40
	Beaconia	0.61	4.86	15.90	7.85	6.14	
	Month mean	2.12	4.73	6.46	9.58		

[1] means are reconverted from transformed raw data = $\sqrt{X + 0.5}$

a peak season - area CUE of 58.33 in Lower Devil Lake (Tables 5, 6). Bullheads were most abundant in May and reached a peak CUE of 204.75 in Upper Devil Lake (Tables 5, 6). Goldeye showed different abundances in different areas at different times. They were most abundant at Upper Devil and Lower Devil lakes in July. Peak CUE's were 97.36 and 73.27 respectively (Tables 5, 6). Northern pike were evenly distributed in all three areas. Their highest abundance was in May (CUE = 21.00). Yellow perch were also evenly distributed in space but had a bimodal seasonal maximum abundance of 10.07 in May and 1.414 in August. Carp were evenly distributed by area with a peak seasonal CUE of 11.31 in May.

Although detailed analyses of catch by weight were not carried out, the most common species for the combined total catch by weight were: carp (45.75%), bullhead (14.77%), pike (8.33%), drum (8.25%), and sauger (5.35%) (Table 7, Appendix G). Other species accounted for 17.55% of the catch.

Temperature - The Netley-Libau Marsh species list was primarily composed of mesotherms (coolwater species) and eurytherms (warmwater species) which combined accounted for 20 of the 25 species caught (Table 8). Stenotherms (coldwater species) were not well represented (3 of 25 total species). The dominant species were evenly divided between mesotherms and eurytherms. Stenotherms were not included among the abundant species. The fall-winter species composition was dominated by mesotherms (Table 8). During early spring (April), mesotherms dominated. During late spring (May-June) eurytherms dominated. In summer, mesotherms were predominant.

Table 7 . Total biomass (gm) of fish captured and percentage species composition of three lakes in Netley-Libau Marsh sampled May through August 1981 by standard gangs of gillnets.

Species	Upper Devil		Lower Devil		Beaconia		Combined	
	biomass	%	biomass	%	biomass	%	biomass	%
freshwater drum	38170	4.76	58530	9.24	74060	11.68	170760	8.25
goldeye	44480	5.55	44930	7.09	3140	0.50	92550	4.47
mooneye	520	0.06			220	0.03	740	0.04
sauger	26070	3.25	76005	11.99	8700	1.37	110775	5.35
walleye	3930	0.49	4860	0.77	1720	0.27	10510	0.51
sucker	57490	7.17	21870	3.45	9150	1.44	85510	4.28
yellow perch	12970	1.62	11970	1.89	15330	2.42	40270	1.95
white bass	540	0.06			1580	0.25	2120	0.10
carp	297880	37.16	236900	37.38	412060	65.01	946840	45.75
n. pike	71320	8.89	61505	9.71	39580	6.24	172405	8.33
quillback	38940	4.86	12270	1.94	10720	1.69	61930	2.99
rock bass	280	0.03	420	0.06	100	0.02	800	0.04
bullhead	170360	21.26	78500	12.39	56820	8.96	305680	14.77
channel catfish	38520	4.80	25950	4.09	760	0.12	65230	3.15
tullibee	360	0.04					360	0.02
Total	801830		633710		633940		2,069,480	

Spawning - Netley-Libau Marsh fishes represented 8 categories when classified by spawning season, spawning temperature, spawning substrate and reproductive strategy (Table 9). Fishes which typically shed eggs over a rock, gravel, rubble or sand substrate were relatively unimportant in the species composition during their spawning period, although they do occur. Fishes that were major constituents of the species composition during their spawning period were of two types. The first type represents fishes that attach eggs to dead, recently flooded or submerged vegetation. Examples of the first type are perch, pike, bigmouth buffalo, carp and white bass. The second type represent fishes which guard eggs deposited in a nest, natural cavity or burrow. Examples of the second type are rock bass, black crappie, bullhead, channel catfish and tadpole madtom.

During fall and winter, the Netley-Libau Marsh fish community was dominated by northern pike which are spring spawners. In early spring (April) the fish community was also dominated by spring spawners. In late spring (May-June) dominance shifted to summer spawning species such as bullhead and carp. During summer (July-August) the fish community is characterized as strongly by spring spawners, such as goldeye, sauger and yellow perch as it is by summer spawning species such as bullhead and freshwater drum.

The general spawning trend in the large fish community was supported by subadult fish collections from Netley-Libau Marsh. The majority of subadult fishes captured represented types that spawn on vegetation or build nests. Freshwater drum, goldeye and shiner subadults were exceptions since either the eggs (e.g. drum) or eleutheroembryo

Table 8. Seasonal community structure of fishes at Netley-Libau Marsh, 1980-1981, expressed according to thermal requirements. Data are species composition by numbers of fish caught expressed as % of total.

Thermal Classification[1]	Species[2]	Season and Month							
		Winter	Spring			Summer		Fall	
		March	April	May	June	July	August	September	October
temperate stenotherm	cisco, burbot, whitefish	0.00	0.00	0.04	0.00	0.00	0.00	0.00	1.28
temperate zone mesotherm	goldeye, mooneye, suckers, walleye, sauger, quillback trout-perch, perch, pike, bigmouth buffalo	88.29	65.51	42.68	32.19	64.48	61.62	84.79	97.44
temperate eurytherm	drum, emerald shiner carp, spottail shiner rock bass, black crappie bullhead, channel catfish tadpole madtom	11.71	34.49	57.28	67.81	35.52	38.38	15.21	1.28

[1] After Hokanson (1977). See also Table 14.

[2] white bass and chestnut lamprey were not classified.

Table 9. Seasonal community structure of fishes at Netley-Libau Marsh, 1980-1981, expressed according to spawning behaviour.

Spawning Season and water temperature	Strategy and Substrate	Species[1]	% proportion by season and month							
			Winter	Spring			Summer		Fall	
			March	April	May	June	July	August	September	October
1. Fall to Spring <15°C	scatter eggs, which nest on rock, gravel or rubble	cisco, burbot whitefish	0.00	0.00	0.04	0.00	0.00	0.00	0.00	1.28
2. Spring 3-23°C	scatter eggs over gravel and rock; larvae distributed by current	goldeye, mooneye	1.56	0.00	2.95	4.86	32.40	20.51	0.00	0.00
3. Spring 3-23°C	scatter eggs which nest on rock, gravel or rubble	suckers, walleye sauger, quillback trout-perch	3.52	5.71	11.82	16.58	14.14	26.23	23.53	0.00
4. Spring 3-23°C	scatter adhesive eggs which cling to dead, recently flooded and submerged vegetation	perch, pike bigmouth buffalo	83.21	59.80	27.91	10.75	17.94	14.88	61.26	97.44
5. Spring-Fall 15-32°C	broadcast eggs into water column. Eggs distributed by currents	drum, emerald shiner	0.00	0.00	2.40	6.77	10.76	6.01	1.96	0.00
6. Spring-Fall 15-32°C	scatter or deposit eggs which cling to dead recently flooded and submerged vegetation	carp	0.00	0.62	16.00	11.01	4.41	5.60	6.62	0.00
7. Spring-Fall 15-32°C	scatter eggs over sand or near fine roots of plants; eggs stay on substrate	spottail shiner	- no data -							
8. Spring-Fall 15-32°C	eggs deposited in prepared area; rock, gravel, veg., natural holes, cavities or burrows. Eggs and young guarded by parents	rock bass black crappie bullhead channel catfish tadpole madtom	11.71	33.87	38.88	50.03	20.35	26.77	6.63	1.28

[1] white bass and chestnut lamprey were not classified

(e.g. goldeye) are distributed by currents (Balon 1975).

Movement - The dominant species at Netley-Libau Marsh were of both non-migratory and migratory types (Table 10). Bullhead are generally considered to be sedentary inhabitants of shallow warm waters with abundant vegetation and sand to mud bottoms. Goldeye, carp, perch and freshwater drum migrate to shallows in spring and early summer to spawn, often remain in shallow water until temperatures begin to drop in the fall and return to deeper areas to overwinter. Northern pike and sauger are often abundant in shallow waters in spring and fall. These species move into shallow waters in spring to spawn, move into deeper waters at the height of summer temperatures and often appear in shallow water again in the fall. Emerald shiners are thought to stay offshore in summer, move inshore in autumn and overwinter in deep water.

Bullheads at Netley-Libau Marsh appeared to follow a seasonal abundance pattern in contradiction to their sedentary classification. Goldeye did not appear to be abundant during spring in contradiction to their theoretical movement pattern but were abundant in summer and low in numbers or absent during winter fishing in agreement with theoretical abundance. Carp followed their theoretical abundance pattern closely as did northern pike, perch and to some extent freshwater drum. Sauger did not show a spring peak in abundance, and were most abundant in summer in contradiction to their theoretical movement pattern. This study did not determine the seasonal abundance pattern of emerald shiners but their occurrence at Netley-Libau Marsh during open water shows that the local movement pattern includes an inshore component which includes the Netley-

Table 10. Seasonal abundance of dominant Netley-Libau Marsh fish by movement pattern[1].

Migratory pattern[2]	Species	Seasonal abundance (% numbers caught)							
		Winter	Spring			Summer		Fall	
		Mar	Apr	May	Jun	Jul	Aug.	Sep.	Oct.
1. Sedentary	bullhead	11.71	33.87	38.63	49.12	19.45	26.29	6.63	1.28
2. Migrate to shallows in spring-early summer to spawn and return to deeper areas to overwinter	goldeye, carp perch, freshwater drum	3.91	15.75	30.49	24.98	56.68	43.52	20.34	12.66
3. Abundant in shallow water in spring for spawning. Also abundant in shallow water in fall. Move to deeper water at peak of summer temperature	pike, sauger	80.86	45.34	23.54	23.00	20.85	24.57	73.03	84.78
4. Stay offshore in summer, move inshore in autumn overwinter in deep water	emerald shiner	- no data -							

[1] Seasonal abundance is based on gillnetting surveys

[2] migratory pattern based on descriptions of biology in Scott and Crossman (1973).

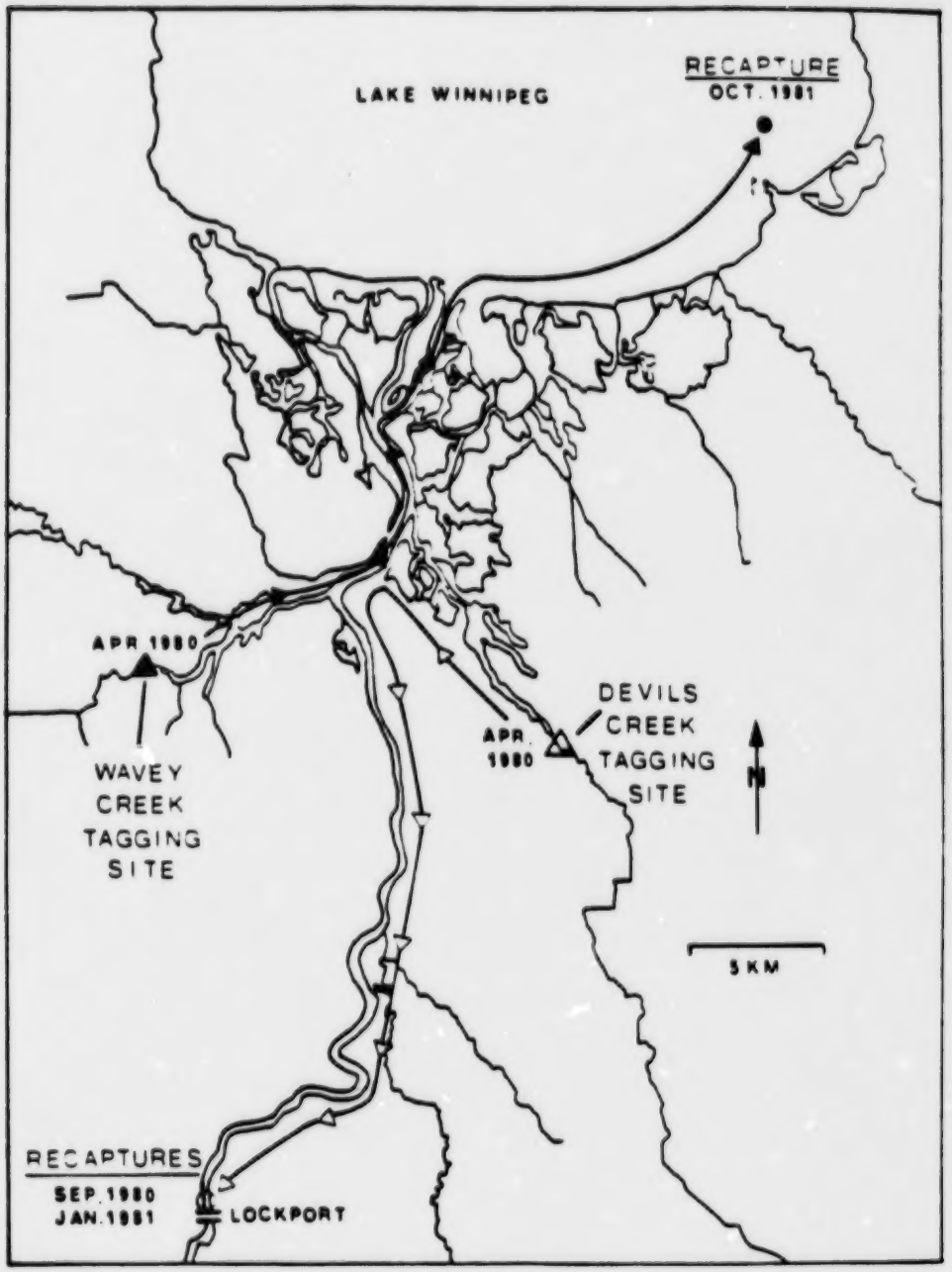

Fig. 9. Tagging and recapture locations of walleyes tagged at Devils and Wavey creeks, Netley-Libau Marsh, April, 1980.

Libau area.

Walleye fall in the same movement category as northern pike and sauger. Three walleyes were tagged in Devils Creek and three walleyes were tagged from a commercial fishermen's trapnet at Wavey Creek during April 1980 (Fig. 9, Appendix K). Three recoveries were made. Walleyes were recaptured between 154 and 529 days after release and had travelled between 30 and 38 km. Two fish were recaptured at Lockport on the Red River by anglers in the fall and winter seasons. One fish was recaptured by a Lake Winnipeg commercial gillnet fisherman during the fall 1981 commercial fishing season.

Feeding - Netley-Libau Marsh fishes represented all major feeding categories, i.e. benthos, zooplankton and fish (Table 11). The winter fish community was dominated by species which primarily feed on fish. The spring fish community was dominated by fish which feed primarily on benthos and fish which feed primarily on fish. The summer fish community was dominated by benthos feeders, piscivores and fish which feed on zooplankton, benthos or fish depending on availability. In fall the fish community was dominated by benthos and fish eating species in September and fish eating species in October.

Yellow perch and shiners were the most abundant recognizable items in sauger stomachs (Appendix L). Most northern pike stomachs examined during winter were packed with mayfly nymphs (*Hexagenia limbata* from keyed specimens) (Appendix L). At other times carp were the most abundant identifiable items in pike stomachs.

Table 11. Seasonal abundance of Netley-Libau Marsh fish by dominant food type[1].

Predominant food	Species[2]	seasonal abundance (% number caught)							
		Winter	Spring			Summer		Fall	
		Mar	Apr	May	Jun	Jul	Aug	Sep.	Oct.
zooplankton	shiners black crappie	- no data -							
benthos	drum* suckers* trout-perch rock bass* channel catfish* bullhead* carp* quillback* tadpole madtom	15.23	39.53	64.07	69.59	35.08	43.08	15.21	1.28
fish	walleye* sauger* pike* white bass*	80.86	45.34	23.67	23.00	21.78	24.79	73.03	84.78
zooplankton/benthos	cisco* whitefish* bigmouth buffalo*	0.00	0.00	0.34	0.00	0.00	0.13	0.00	1.28
benthos/fish	burbot	- no data -							
zooplankton/benthos fish	perch* goldeye* mooneye*	3.91	15.13	11.92	7.41	43.14	32.00	11.76	12.66

[1]Seasonal abundance is based on gillnetting surveys

[2]asterisk indicate species included in abundance calculations. Species not indicated by an asterisk were not caught in gillnets.

Population dynamics - There was significant agreement between ageing structures over a substantial age range for both sauger and goldeye and scale ages were selected as the basis for population parameter estimates (Appendix M).

Saugers ranged in age from 1+ to 8+ years (Fig. 10, Appendix M). The age composition was positively skewed with a modal age of 2+. The most abundant age groups were 2+, 3+ and 4+ which made up more than 70% of the catch. Annual survivorship was estimated as 28% for ages 5+ and older (Fig. 11, Appendix M). Growth in length and weight was nearly isometric (slope = 2.887) (Tables 22, 23). Asymptotic size was L_∞ = 380.30 mm (Fig. 12, Appendix M). The Brody growth coefficient was K = 0.26 while the hypothetical age for zero length was t_o = -1.66 (Appendix M). The corresponding von Bertalanffy growth curve was (Fig. 12):

$$L_t = 380.30\ (1-e^{-0.26(t+1.66)})$$

The mean size at each age of Netley-Libau Marsh saugers tended to be greater than that of Lake Winnipeg south basin saugers (Lysack 1980, 1981). Sex ratio was approximately 1:1 (Appendix M). Estimated age of 50% maturity for male, female and both sexes combined was approximately 2 years. Since fish spawning for the first time during the upcoming year were not separated from previous spawners the maturity rate is however overestimated while the mean age of maturity is underestimated (Olynyk 1980).

Northern pike ranged in age from 1+ to 10+ years (Fig. 10, Appendix M). Their age composition was positively skewed with a modal

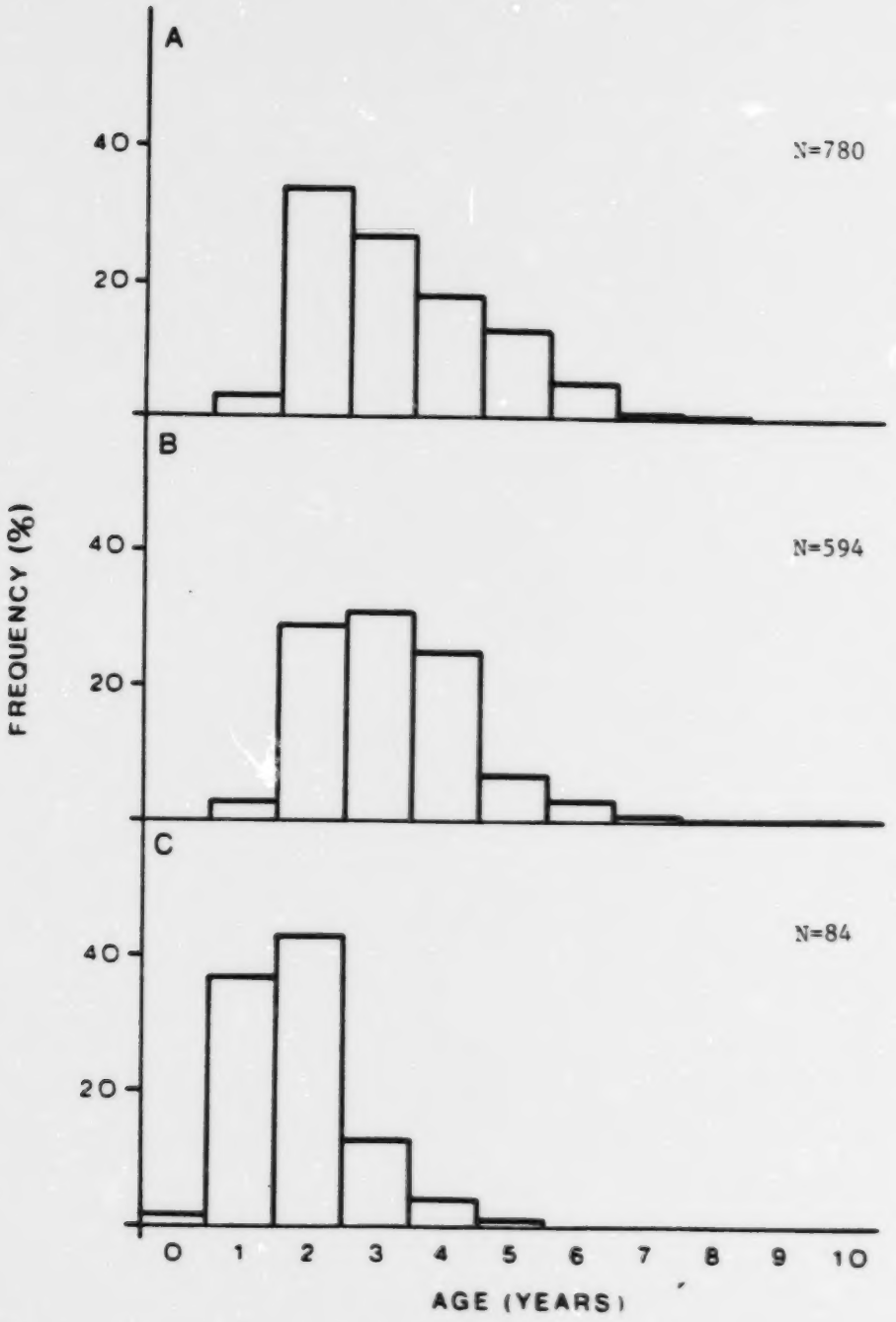

Fig. 10. Age compositions of sauger (A), northern pike (B), goldeye (C) in Netley-Libau Marsh, 1980-1981.

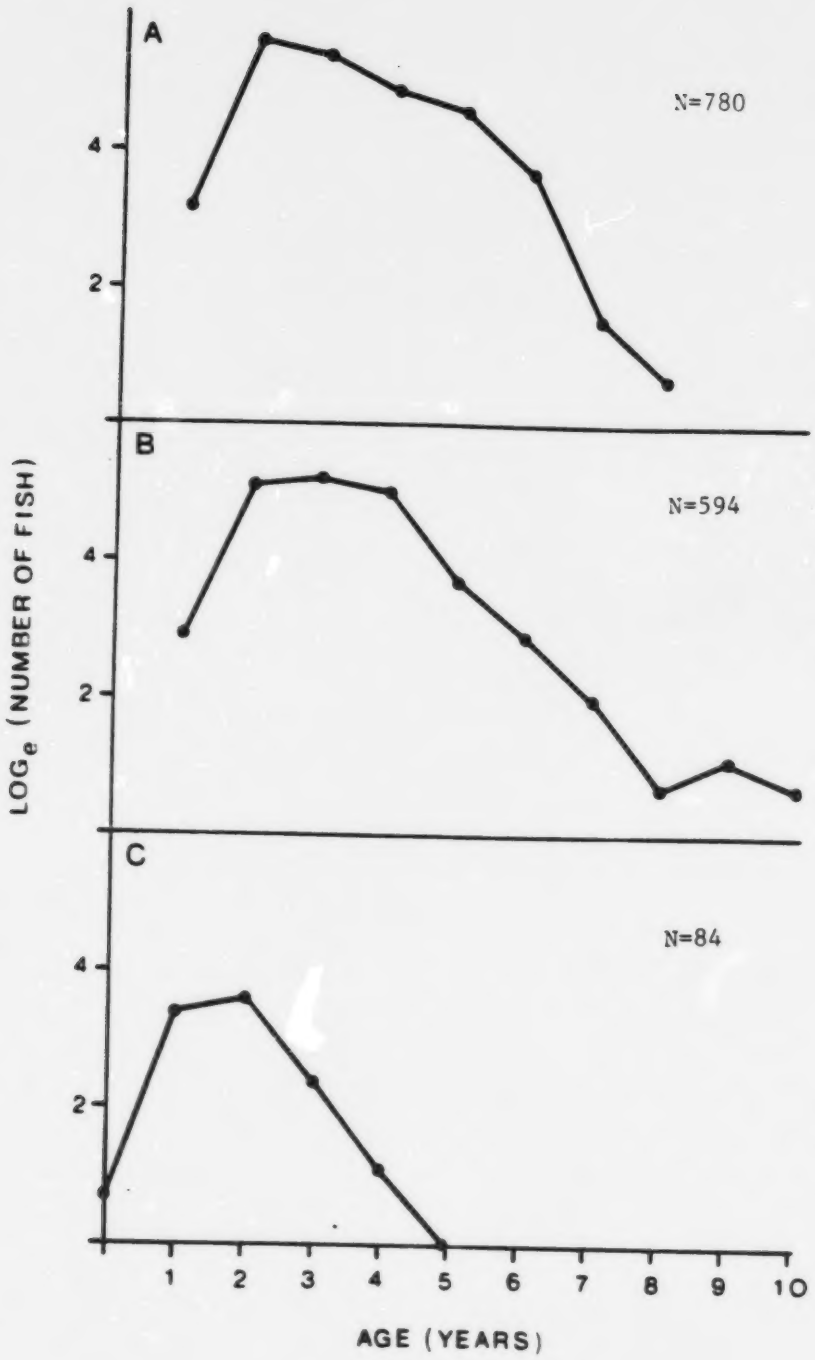

Fig. 11. Catch curves of sauger (A), northern pike (B), and goldeye (C) in Netley-Libau Marsh, 1980-1981.

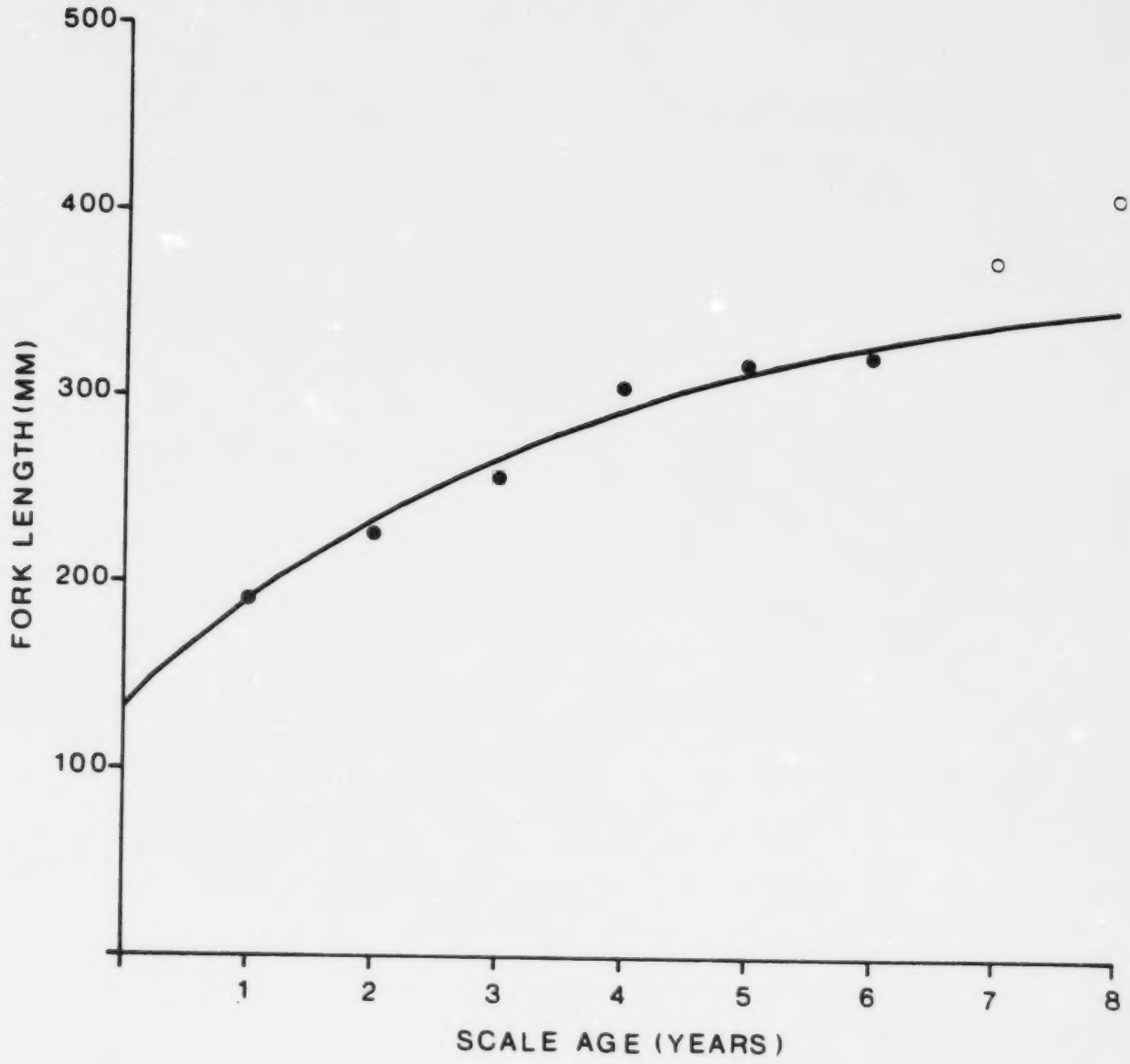

Fig. 12. Von Bertalanffy growth curve for length of sauger of Netley-Libau Marsh, 1980-1981. Open circles show points not included in calculations.

age of 3+ years. The most abundant age groups were 2+, 3+ and 4+ which comprised over 80% of the catch. Annual survivorship was estimated as 38% for ages 4+ and older (Fig. 11, Appendix M). Growth in length and weight was nearly isometric (slope = 2.997) (Appendix M). Asymptotic size was L_∞ = 820.50mm (Appendix M). The Brody growth coefficient was K = 0.20 while the hypothetical age for zero length was t_o = 0.45. The corresponding von Bertalanffy growth curve was (Fig. 13):

$$L_t = 820.50\ (1-e^{-0.20\ (t+0.45)})$$

Mean sizes at each age approximated those of pike from other Canadian locations (Scott and Crossman 1973). Sex ratio was approximately 1:1 (Appendix M). Estimated age of 50% maturity for male pike, females and both sexes combined was approximately one year (Appendix M). As with sauger the maturity rate is an overestimate and consequently the mean age of maturity is underestimated.

Goldeye ranged in age between 0+ and 5+ years (Fig. 10, Appendix M). Modal age was 2+. The most abundant age groups were 1+, 2+ and 3+ which comprised over 90% of the catch. The data supported a simple survivorship curve for the entire descending limits of the catch curve (Fig. 11). Annual survival was estimated as 29% for ages 2+ and older (Appendix M). Growth in length and weight was slightly allometric (slope = 3.414) (Appendix M). Asymptotic size was L_∞ = 266.53mm (Appendix M). The Brody growth coefficient was K = 0.74 while the hypothetical age for zero length was t_o = 0.53. The corresponding von Bertalanffy growth curve was (Fig. 14):

$$L_t = 266.53\ (1-e^{-0.74(t+0.53)})$$

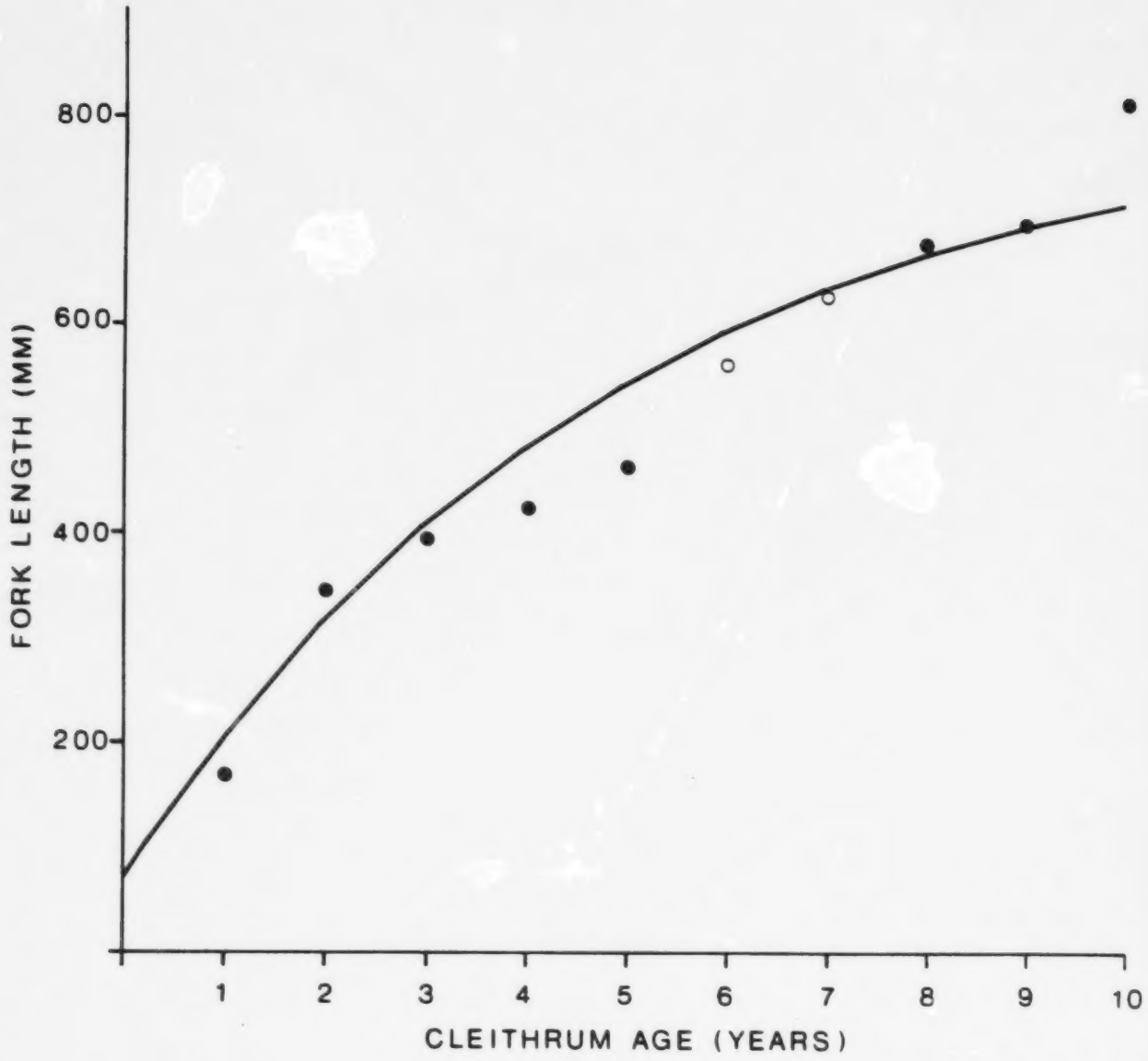

Fig. 13. Von Bertalanffy growth curve for length of northern pike of Netley-Libau Marsh, 1980-1981. Open circles show points not included in calculations.

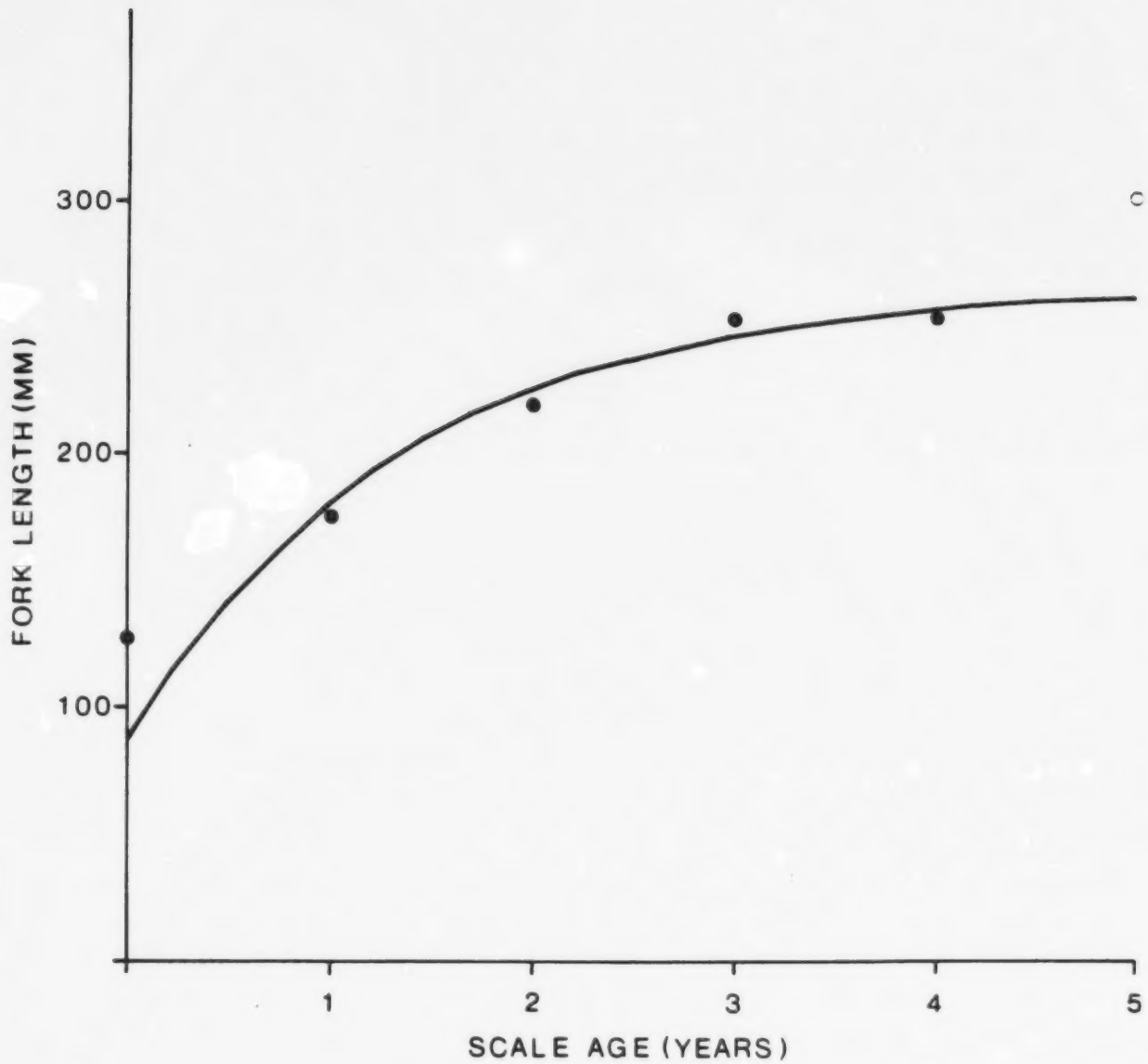

Fig. 14. Von Bertalanffy growth curve for length of goldeye of Netley-Libau Marsh, 1980-1981. Open circles show points not included in calculations.

The mean sizes at each age of goldeyes approximated the fastest reported growth in Canadian waters (Scott and Crossman 1973). Sex ratio and maturity rate were not estimated for goldeyes.

ASSOCIATED FISHERIES

Fishing in the Netley-Libau Marsh is limited due to poor access, complex topography, and current fishery regulations. Gillnet fisheries, similar to those on Lake Winnipeg are prohibited in the Red River and up to one mile into Lake Winnipeg from the river mouth. Angling, commercial bait fishing and spring commercial rough fish fishing were observed during 1980. A commercial carp fishing operation was observed in 1981.

Anglers tended to concentrate at the mouths of tributary streams such as Devils Creek as well as at the breached levee of Netley Lake. Anglers did not venture into the interior of the marsh to any great extent. This most likely is due to the possibility of becoming lost in the complex channel system. Miller (1972) reported that, in 1969, most of Manitoba's bowfishing effort, exploiting primarily carp, took place at Netley-Libau Marsh. Bowfishing activity was not seen in 1980 or 1981, but is still reputed to occur.

Commercial bait fishing activity was observed in interior marsh channels near Devils Creek and in the Red River mainstem near Netley Creek involving two different bait fishermen. Fisheries Branch issues about 11 bait fish licences annually to Netley-Libau and Red River area

residents (G. Nelson pers. comm.[1]).

Spring commercial rough fishing (primarily suckers) in Manitoba has a history of about 25 years. It is conducted primarily in tributary streams to Lake Manitoba which may produce 450-900 thousand kg in good years. This tradition has not included the Netley-Libau area although it is thought that the potential may be there (K. Campbell pers. comm.[2]).

In 1980, several spring rough fish licences were issued for the Netley-Libau area. Interest at Netley-Libau is thought to have occurred as a result of good prices for suckers associated with a Freshwater Fish Marketing Corporation (FFMC) sales contract for 1.4 million kg of suckers (K. Campbell pers. comm.). Six fishermen indicated their intention to fish Devils Creek, Goldeye Creek, Wavey Creek, the Brokenhead River and Cook's Creek immediately south of the marsh. The only activity noted in the Netley-Libau area was at the Brokenhead River, Cook's and Wavey creeks. Brokenhead River catches were in the order of 3600 kg of sucker and 3600 kg of carp along with some other rough fish species (K. Campbell pers. comm.). A visit to commercial trapnets at Cook's and Wavey creeks on April 25, 1980, showed bullhead, freshwater drum, channel catfish, black crappie, quillback, sucker, walleye, pike, carp and yellow perch comprising the catch in approximate order of abundance. Bullhead were the only species being marketed at the time and were sold at a nominal price

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[1]Sport Fishing Section, Manitoba Department of Natural Resources.

[2]Fisheries Manager, Interlake Region, Manitoba Department of Natural Resources.

to a nearby rough fish processing plant. Fishermen expressed disappointment in sucker catches which they attributed to low flows and low water levels. Incidental walleye catches were in the order of 20 fish per overnight set in early April, but quickly dropped off as spring flow decreased.

In 1981, commercial pound net fishing for carp took place at Beaconia Lake during May. Fishermen reported catching approximately 3600 kg of carp in each of two sets. They reported their species composition as 98% carp plus a limited amount of other rough fishes. The fishermen were interested in fishing the marshes more extensively, but were concerned about lack of access for trucks to marsh areas.

Waters connecting with the Netley-Libau Marsh support three of Manitoba's largest and most economically important fisheries.

The Lake Winnipeg commercial gillnet fishery harvests 37% of Manitoba's total production annually with a value to fishermen of 4 million dollars (Table 12).

The Red River sport fishery is considered to be one of Manitoba's foremost recreational fisheries in terms of angler use. Don Toews (pers. comm.[1]) has suggested that the Red River may receive up to 15-20% of Manitoba's resident licenced angler effort based on the 1980 sport fishing survey. This would amount to some 400,000 angler days with a total gross value of 14 million dollars (estimated by proportion of total

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[1]Chief of Sport Fishing, Manitoba Department of Natural Resources, Fisheries Branch.

Table 12. Mean annual production and value of commercial fish species from Manitoba and Lake Winnipeg 1975-79[1].

Species	Manitoba		Lake Winnipeg		L. Wpg. as % of Man. total	
	Kg.	$	Kg.	$	Kg.	$
whitefish	3,204,993	2,324,841	1,218,441	1,124,895	38.02	40.39
walleye	2,803,102	3,710,806	1,351,923	1,750,205	48.23	47.17
sauger	1,452,349	1,524,133	1,287,425	1,327,695	88.64	87.11
pike	2,186,268	695,361	378,331	121,757	17.30	17.51
tullibee	287,159	115,227	52,001	23,768	18.11	20.63
trout	41,499	21,328	-	-		
goldeye	12,118	5,191	1,054	418	8.70	8.05
perch	49,496	31,634	38,827	24,189	70.45	76.47
carp	298,008	39,163	55,669	10,283	18.68	26.26
burbot	1,035	188	136	67	9.86	2.19
freshwater drum	9,506	2,004	9,245	1,979	97.25	98.75
sturgeon	8,562	25,794	40	125	0.47	0.48
catfish	6,532	1,650	6,532	1,650	100.00	100.00
sucker	1,877,658	230,392	92,454	11,624	4.92	5.05
	12,238,285	8,727,712	4,492,079	4,398,655	36.71	50.40

[1]Data from Department of Natural Resources annual reports 1975-79.

Manitoba effort and expenditure). The total Red River harvest and the harvest of component species is unknown. A review of trophy species in the Red River between 1975-1979 shows that the Red River produced more trophy walleye than any other river system in Manitoba (Table 13). The walleye is Manitoba's most important sport fish (Table 13). The Red River was also first in Master Angler awards for sauger, bullhead, carp and channel catfish (Table 13). The Red River was second in Master Angler awards for goldeye and freshwater drum (Table 13).

The Lake Winnipeg-Red River bait fishery is also one of Manitoba's foremost fisheries. Although the bait fishery has not been studied, knowledgeable estimates suggest that 60-70% of Manitoba's bait fish production, worth $300,000 annually, is harvested by 19 operators in the Red River-Lake Winnipeg area. Shiners are known to be the major constituent of this bait fishery.

Table 13. Manitoba sport fish species and important Red River sport fish species.

Species	Relative Manitoba importance[2]	Trophy importance of Red River relative to major Manitoba river systems
walleye	1	1
pike	2	
perch	3	
sucker	4	
*smallmouth bass	5	
*lake trout	6	
*brook trout/speckled trout	7	
sauger	8	1
goldeye	9	2
*rainbow trout	10	
*splake	11	
whitefish	12	
freshwater drum	13	2
bullhead	14	1
other	15	
*Arctic grayling		
*brown trout		
burbot		
carp		1
channel catfish		1
*largemouth bass		
mooneye		
*muskellunge		
rock bass		
*sturgeon		
*Arctic char		

[1] species appear either in O'Connor (1978) or Manitoba Master Angler award lists 1975-79

[2] relative importance is based on O'Connor (1978) Table 1. Success (no. kept) according to the 1975 sport fish survey

[3] based on Manitoba Master Angler award lists 1975-79

* not found in Netley-Libau Marsh in 1980-1981

DISCUSSION

The Netley-Libau Marsh, in its present form, represents a unique and dynamic fish habitat in the Lake Winnipeg-Red River area. The marsh is currently a slightly modified, productive shallow water zone open to influences from adjacent waters. Hydrologic connectivity and high trophic status result in open water utilization by important fishes from the Red River and Lake Winnipeg as a spawning, nursery and feeding area. The dependency of fisheries production in lakes and rivers on the availability of habitat like Netley-Libau Marsh, the large size of the marsh and the economic importance and intensity of fishing in the Red River and Lake Winnipeg argue for the preservation of these values. Intuitively, it seems wise to accept the world experience of development on the fish resources of similarly structured habitats as a guideline for the protection of the Netley-Libau Marsh fish resource.

PHYSICOCHEMICAL FEATURES

The Netley-Libau Marsh is unique because it is the largest of Lake Winnipeg's peripheral marshes. It is also unique because the Red River is the only major tributary to Lake Winnipeg to have a significant deltaic formation at its point of entry to Lake Winnipeg.

Upstream damming, tributary channelization, peripheral dyking and Lake Winnipeg regulation represent the first of Welcomme's (1979) cutting points in the typical pattern of river modification. The lack

of water control structures within the marsh and the lack of artificial restrictions to fish movement suggest that the second cutting point marking the transition from slight to extensive modification has not yet been reached. The spring flood peaks of the Red River and tributaries like Devils Creek, as well as the periodic water level fluctuations caused by Lake Winnipeg suggest that the flood regime is also still largely unaltered. Shallow depth and freezing of marsh lakes in winter point to the maintenance of the natural alternating "flood and dry" season characteristic of floodplains (Welcomme 1979) (Fig. 15). Continuity with the Red River and Lake Winnipeg, the seasonal flood cycle and water level fluctuations caused by wind setup on Lake Winnipeg imply the maintenance of pulse stability.

The temperature regime is most satisfactory for temperate mesothermal freshwater fish (Table 14). Stenothermal fish would have less than optimum conditions for gonadal development and growth. Maximum marsh temperatures reach the ultimate upper incipient lethal level range for stenotherms. Conditions for eurythermal fishes are generally good except that maximum water temperature is below their physiological optimum. Conditions for mesothermal fish are nearly optimum. Fall and winter temperatures were adequate for gonadal growth. Spring temperatures provided spawning requirements. Summer temperatures were within the range of the physiological optimum. Maximum recorded water temperatures were below the ultimate upper incipient lethal temperature.

Seasonal variation in oxygen availability further emphasizes the seasonal cycle within the Netley-Libau Marsh. Oxygen is the major

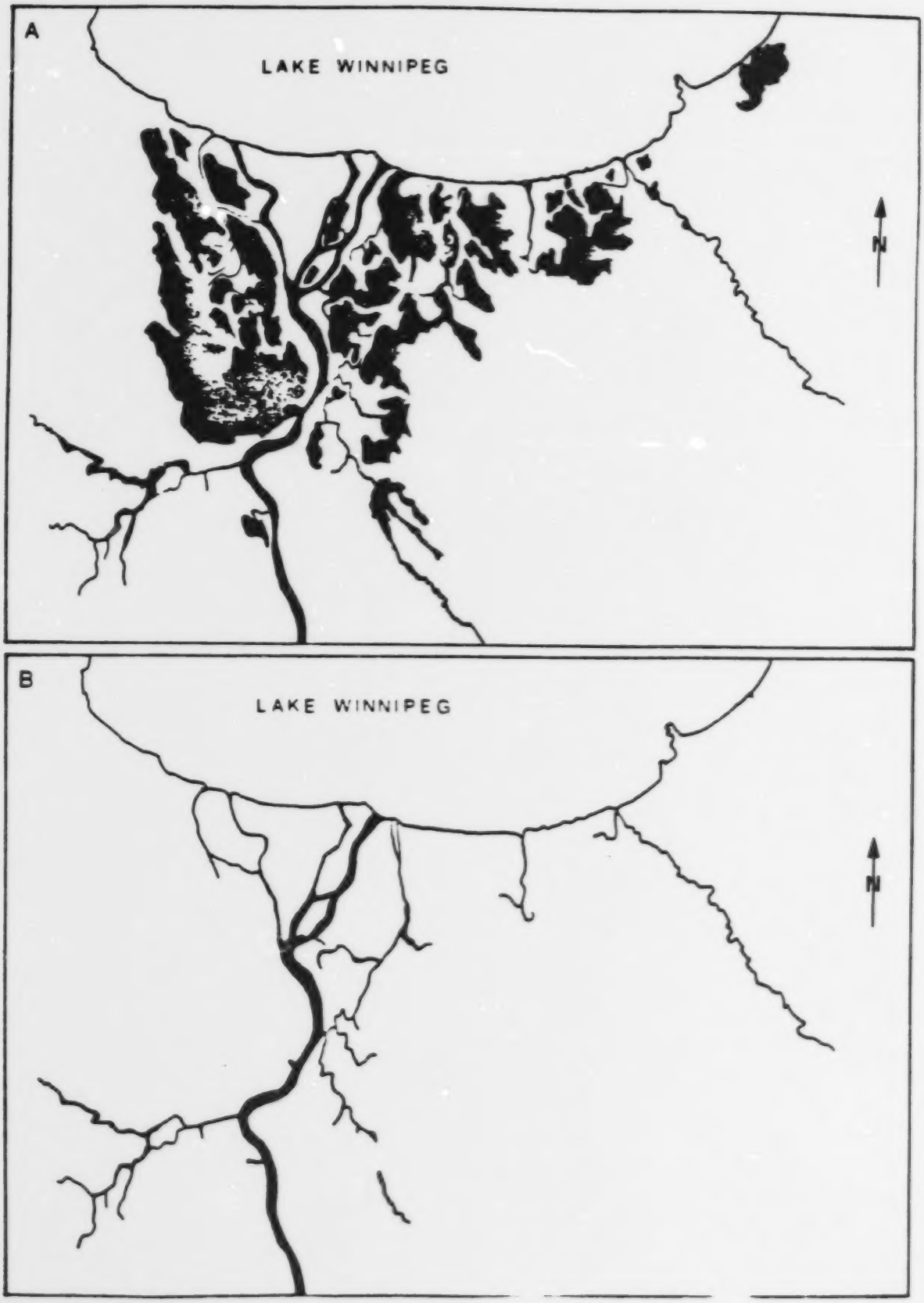

Fig. 15. Expected extent of fish habitat of Netley-Libau Marsh in A - summer and B - winter.

Table 14. Temperature requirements of temperate-climate[1] freshwater fish[2].

Classification	Criteria	Example Species
Temperate stenotherm	Gonadal growth phase in summer, <20°C Spawning in fall to spring, <15°C Physiological optimum, <20°C Ultimate upper incipient lethal temperature, <26°C	Lake herring *(Coregonus artedii)*
Temperate mesotherm	Gonadal growth phase in fall and winter, <12°C Spawning in spring, 3-23°C Physiological optimum 20-28°C Ultimate upper incipient lethal temperature, 28-34°C	Northern pike *(Esox lucius)*
Temperate eurytherm	Gonadal growth phase during long days, >12°C Spawning in spring to fall, 15-32°C Physiological optimum, 28°C Ultimate upper incipient lethal temperature, >34°C	Carp *(Coregonus carpio)*

[1]The use of the term temperate as a prefix in classification represents the ability to most temperate-climate species to survive temperatures near freezing (<4°C). Therefore, description of a species' thermal requirements reflects their relative biokinetic range of tolerance, performance and activity.

[2]after Hokanson (1977).

physical limiting factor in aquatic ecosystems (Odum 1971). At oxygen levels below 47% saturation mixed populations of freshwater fishes may begin to exhibit symptoms of oxygen distress (Davis 1975). During winter at Netley-Libau Marsh oxygen levels in excess of 47% are probably found only in deeper channels with hydrological connectivity to the surrounding waters of the Red River and Lake Winnipeg. Fish become more active in hypoxic waters and attempt to move away from low oxygen regimes (Davis 1975). The occurrence of this behavioural response will depend on a species specific ability to acclimate to gradually reduced oxygen tension and the species specific threshold oxygen tension for avoidance behaviour (Davis 1975). During winter at Netley-Libau Marsh the presence or success of any fish species will depend on its ability to withstand low oxygen levels in channel areas where the oxygen gradient is <47% saturation. In contrast, open water oxygen levels in marsh lakes were in excess of Davis's (1975) guideline for the maintenance of a mixed population of freshwater fish. At this time the presence or absence of a species will not be as limited by oxygen levels since the oxygen supply is within the tolerance range for a wide variety of species. Vertical oxygen gradients are well known from floodplains (Welcomme 1979). Photosynthetic activity raises oxygen content during the day, particularly near the surface, but dissolved oxygen is withdrawn by plants and the biochemical oxygen demand of silt and suspended organic solids at night (Ducharme 1975). Vertical open water oxygen gradients at Netley-Libau Marsh would not be expected to adversely affect fish populations since oxygen is >47% saturation both top and bottom (Davis 1975).

Water chemistry results suggest that Netley-Libau Marsh has a relatively high trophic status. Ionic ratios show that Netley-Libau Marsh lakes contain mixed or intermediate bicarbonate-sulfate waters of mixed calcium-magnesium or magnesium-calcium subtype (Barica 1975). TDS values fall within the typical range for freshwater lakes overlying sedimentary deposits in Canada's Western plains (Northcote and Larkin 1963). According to Reid (1961) the Netley-Libau Marsh chemistry may be described as alkaline hard waters which are "rich" in nutrients since pH is >8.5 and calcium is >25 $mg.\ell^{-1}$. Hard water, calcium rich lakes usually contain more living matter per unit area than waters with lower pH and calcium levels (Reid 1961). Potential fish standing crop from total phosphorous for Netley-Libau compares favourably to the 277.8 $kg.ha^{-1}$ actual total standing crop found by Mahon and Balon (1977) in a semi-isolated lakeshore lagoon on Long Point, Lake Erie. Mahon and Balon considered their standing crop estimate to represent a relatively high biomass level because it exceeded mean values of 231 $kg.ha^{-1}$ (Jenkins 1968) and 260 $kg.ha^{-1}$ (Hall 1974) respectively for 127 and 27 North American reservoirs. Locally, the south basin of Lake Winnipeg, an area considered to be highly productive for fishing, with a mean total phosphorous concentration of $\sim$69 $\mu g.\ell^{-1}$[1], has a potential standing crop of 119 $kg.ha^{-1}$ and yield of 5.76 $kg.ha^{-1}.yr^{-1}$. From this point of view the tested Netley-Libau Marsh lakes have a potential fish productivity which is 3-4 times higher per unit area than the south basin

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[1]Lake Winnipeg at Victoria Beach, Environment Canada, 1978.

of Lake Winnipeg. Although indirect, PFC and PFY estimates for Netley-Libau Marsh may not be unrealistic. Fish yields predicted from chlorophyll a (representative of primary productivity in terms of summer phytoplankton standing crop) were essentially the same as those predicted from total phosphorous. Similarly the yield estimate for Lake Winnipeg's south basin compares favourably with the Lake Winnipeg south basin historical yield of walleye and sauger. The combined yield of these two species was between 5 and 6 $kg.ha^{-1}$ in the 1940's and 1950's prior to overfishing (Dept. Natural Resources production records).

Physically and chemically wetlands have high fisheries value when they are hydrologically connected shallow water zones with relatively high nutrient levels. The Netley-Libau Marsh is both shallow and continuous with Lake Winnipeg and the Red River. Its nutrient levels are probably higher than those in the majority of Lake Winnipeg's south basin and are consistent with a high trophic status classification. As with most wetlands the Netley-Libau Marsh's most significant feature is its seasonal variation in limiting factors. During open water, temperature conditions for mesothermal fish indicate potentially excellent growth and survival. The less than optimum conditions for stenotherms and to some extent for eurytherms are to be expected due to long term climatic conditions. Steno and eurythermal species are naturally most heavily distributed either north (stenotherms) or south (eurytherms) of the Netley-Libau area. Open water oxygen conditions also appear to be non-limiting. Assuming that other factors, such as turbidity, are non-

limiting it is to be expected that fish would use the Netley-Libau Marsh during open water. In contrast, winter freezing of the marsh causes a great reduction in area available for utilization. This is accentuated by oxygen gradients in waters that are not frozen. Fish could be expected to retreat to the deeper waters of the Red River and Lake Winnipeg at this time of year. The seasonal cycle emphasizes the importance of hydrologic connectivity to fish populations. They must be able to invade and retreat as physical conditions dictate. This is a natural wetland feature. It does not detract from the fact that physically and chemically the Netley-Libau Marsh conforms to the potentially high fisheries values associated with shallow water zones as outlined by Peters et. al. (1978), Welcomme (1979), Hanson and Leggett (1982) and others.

THE FISH COMMUNITY

The fish community associated with Netley-Libau Marsh is consistent with what might be expected from physicochemical features. The fish community is reasonably diverse. Species composition changes seasonally. During winter the fish community is reduced. During open water the fish community is abundant and spawning, nursery and feeding uses of the marsh are indicated. Population dynamics support the general conclusion that the fish community of Netley-Libau Marsh results from cyclical movements by Red River-Lake Winnipeg fish populations into and out of Netley-Libau Marsh.

The twenty-five fish species from Netley-Libau Marsh suggest

a reasonably diverse species list since most of the common commercial and recreational species known from the Red River and Lake Winnipeg occur. The number of species falls short of the historical species list for the Red River in Manitoba which includes 76 species (International Garrison Diversion Study Board 1976). Similarily the historical species list for the south basin of Lake Winnipeg includes 56 species (International Garrison Diversion Study Board 1976). A short fisheries survey cannot expect to duplicate historical totals. Clarke et. al. (1980) for instance only caught 35 species in a survey of the Red River at Winnipeg. There is good agreement between Netley-Libau Marsh species number and Horn's (1980) data from California. Horn (1980) found 21-29 species in relatively unaltered areas and 16-23 species in altered areas.

The most general description of the Netley-Libau fish fauna indicates a meso-eurtherm fish community having tropical fish community parameters for unaltered-slightly modified shallow water situations. The dominance of the fish community by meso-eurythermal species agrees with the expected fish community based on temperature regime. Allen and Horn (1975) found that at least 75% of sampled fish in studies of temperate bay-estuarine fish populations belonged to five or fewer species even though more species were collected. This is true of the Netley-Libau Marsh fauna as well. Although eight species/types were abundant, five or less species dominated the Netley-Libau Marsh community at any particular time. With overall diversity $H' > 1.00$ and a wide range in similarity the Netley-Libau fish community shows characteristics of both the unaltered and somewhat modified situations as defined by Horn (1980). In

this case however the exceptionally wide PS range may be attributable more to severe northern winters than to habitat alterations or environmental pollution. Certainly the diversity and similarity patterns of the well marked seasonal cycle show the utility of Haedrich's (1975) model. During the poor environmental conditions of the late fall-winter period the Netley-Libau Marsh fish community shows a marked reduction in number of species ($H' < 1.00$) and very little change in species composition ($PS > 80\%$). During the good environmental conditions of the open water season the Netley-Libau Marsh fish community has a good variety of species ($H' > 1.00$) with a significant similarity difference from the fall-winter situation coupled with species composition changes over the course of the open water period.

Detailed description of the fish community suggests good agreement with Welcomme's floodplain utilization concept. Each of the three major species compositions at Netley-Libau Marsh corresponds to expectations based on this concept.

The least complicated fish species composition, the fall-winter period, is best characterized as being tolerant of extreme environmental conditions. During fall and winter most of the marsh is frozen. Fish populations could be expected to retreat as freezing occurs. Fishing in the remaining non-frozen waters of the marsh suggested that this was the case. The dominance of the fish community by a single species, northern pike, indicates that the fish community is substantially reduced. The northern pike is noted for high tolerance of low temperature and oxygen conditions (Casselman 1978). Although not dominant, the second most

abundant winter species, bullhead, have a similar reputation. They can live at oxygen levels of 0.2 mg.ℓ^{-1} in winter and may burrow into the bottom mud to avoid adverse conditions (Scott and Crossman 1973). Neither species spawn during fall and winter so that the winter fish community is clearly not classified as a spawning assemblage although a late winter prespawning congregation of pike might be expected. Adult pike usually have a piscivorous diet but are opportunistic and will feed on whatever is most available (Scott and Crossman 1973). Bullhead are benthic feeders. At Netley-Libau Marsh pike feed primarily on young carp during the open water season. Pike stomachs examined during winter were in many cases packed with mayfly nymphs indicating the possible lack of forage fish in marsh channels. This characterizes the winter fish community as having a benthic feeding style. Although benthic feeding may be intense, feeding style in the fish community is not diverse and the winter fish community is perhaps not characterized by a generally intensive feeding style.

As temperatures rise in the spring the marsh thaws and becomes available for occupation by fish. Fish community diversity increases and there is a general shift in the fish community away from strictly condition tolerant types. The relative abundance of fish at Netley-Libau Marsh, measured as standard gang CUE, indicates abundant open water populations. Total standard gang CUE for the dilute Precambrian shield lakes studied by Hagenson and O'Connor (1980) was 32-68 fish.24h^{-1}. Gaboury and Patalas (1981) show a standard gang CUE of 48-180 fish.24^{-1} for

Cross and Pipestone lakes[1] under summer drawdown conditions. The open water Netley-Libau CUE (108-159 fish.24h^{-1}) indicated a populous fish fauna assuming that the quoted examples approximate the true Manitoba range.

The general change in the fish community is shown initially by an early open water species composition which is best characterized as a spawning assemblage. During April, the Red River and its tributaries have maximum flow rates and temperatures favourable to spring spawning fish. The Netley-Libau Marsh fish community during this period was dominated by spring spawners such as pike and yellow perch (Fig. 16). In May and June dominance shifted to summer spawning species such as bullhead and carp (Fig. 16). The Netley-Libau Marsh temperature record shows that this shift is approximately in phase with rising water temperatures which reach the spring-fall spawning temperature range of 15-32^{o}C in May (Fig. 16). As indicated by Welcomme (1979) reproductive use of floodplains by fish populations is usually highly seasonal and often coincides with the earlier phases of the flood.

As a spawning ground the Netley-Libau Marsh is probably most critical for phytophils. Most species of pike and carp are adapted to spawn on freshly flooded vegetation. Spawning cannot take place if this requirement is not met (Balon 1975). The Netley-Libau Marsh is also probably important to nesting-guarding and semi-phytophilous fish. Bullheads build nests among the roots of aquatic vegetation in addition to mud or

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[1]CUE was calculated from catch by mesh size to exclude 1.3 cm mesh size. Data were provided by Gaboury (pers. comm.)

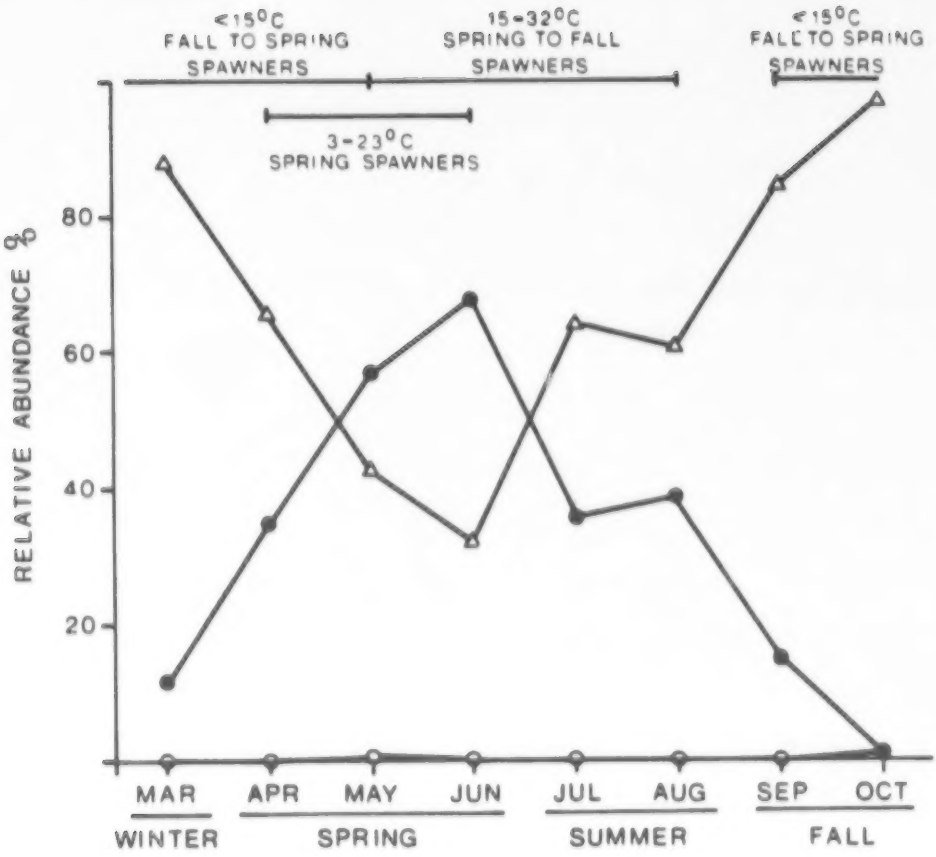

Fig. 16. Relative seasonal abundance of fish at Netley-Libau Marsh 1980-1981 by spawning groupings. Bars show approximate spawning periods according to the Netley-Libau Marsh temperature regime. Δ shows the relative abundance of spring spawning fish. ● shows the relative abundance of summer spawners. O shows the relative abundance of fish which spawn from fall to spring.

sand bottoms, under boards, in hollow stumps or even inside automobile tires nailed on docks as boat fenders. Rooted vegetation, submerged brush or fallen trees are primary substrates to which the yellow perch attaches its egg mass. The low abundance levels during spawning periods of walleye, suckers, goldeye and other rock, cobble, or firm bottom spawners was not unexpected given the generally soft bottom type. Priegel (1970), however, showed that spawning walleyes preferred flooded marshes to either reefs along lakeshores or mainstem river areas in the Lake Winnebago area of Wisconsin. Mats of vegetation were used as a spawning substrate (Priegel 1970). Goldeye are thought to spawn in pools of turbid rivers or in lakes and backwater ponds (Kennedy and Sprules 1967). Shallow areas which either freeze to the bottom or are so stagnant in winter that goldeye could not survive are typical goldeye spawning areas (Kennedy and Sprules 1967). Large numbers of goldeye were hatched in flooded marsh areas of the Saskatchewan delta in Manitoba, either because parents spawned there, or because semibuoyant eggs, though spawned elsewhere, were carried there by currents (Kennedy and Sprules 1967). Priegel (1970) found that low water levels drastically altered the spawning habits of walleye in Wisconsin and resulted in a greater degree of spawning in less desirable habitats. Other authors have linked strong walleye spawning runs to intermediate and large streamflows in Minnesota while variations in walleye year class strengths have shown positive associations to river discharges in Lake Huron, Ontario and Cedar and Moose lakes in Manitoba (Olson and Scidmore 1962, Winterton 1975; Derksen 1967). Welcomme (1979) suggested that the reproduction of floodplain spawners may fail

if flooding is delayed or inadequate to trigger migration. The failure of a number of floods in succession can so weaken the stock that it may be difficult for it to recover, especially if fishing activity in the system is intense (Welcomme 1979). Since spring runoff in 1980 and 1981 at Netley-Libau Marsh was less than average it is premature to conclude that a low level of spawning use, at least by walleye and goldeye, was representative of average conditions.

Analysis of young-of-year fish collections indicated that Netley-Libau Marsh is important as a nursery area for the phytophil, semi-phytophil and nesting/guarding fishes which show evidence of spawning activity. Young-of-year fish collections demonstrate that Netley-Libau Marsh also acts as a nursery area for pelagophils. Balon (1975) classified both freshwater drum and emerald shiners as pelagophils. Pelagophils tend to release and scatter their eggs in open water where the direction of the current is favourable to their distribution and survival (Balon 1975). In rivers this strategy may involve upstream (spawning) migrations (Balon 1975). Eggs often develop while being carried along in the current (Balon 1975). Although the spawning behaviour of freshwater drum is not well known it seems likely that either spawning within the marsh or passive larval drift is responsible for the presence of young-of-year at Netley-Libau Marsh. The presence of probable young-of-year emerald shiners at Netley-Libau Marsh is explained in the same way.

The spawning species assemblage at Netley-Libau Marsh is followed by the late open water species composition which is best characterized as a feeding assemblage. During July and August the fish

community is dominated as strongly by spring spawners as it is by summer spawning species. This suggests that the species composition is not a result of spawning activity. Alternatively, the summer fish community shows the greatest diversity in feeding style involving piscivorous, benthic, zooplankton, and opportunistic feeding species. The fish community at this time is particularly marked by increases in abundance of spring spawning predatory species, most notably goldeye, sauger and yellow perch. These three species combined account for over 50% of the species composition by numbers in July and August.

The high trophic status of Netley-Libau Marsh is exploited by fish through their food requirements. During the open water season at Netley-Libau Marsh phytoplankton and zooplankton populations can be expected to peak in abundance. This is beneficial to young-of-year fish which feed on items such as algae, zooplankton, and the immature stages of aquatic insects. Summer abundance peaks for adult sauger, goldeye and yellow perch are probably due to feeding strategies which take advantage of generally high open water productivity as well as the occurrence of young-of-year fish. Adult sauger feed on small fishes and invertebrates (Scott and Crossman 1973). In Lake Winnipeg's south basin, young-of-year and yearling sauger fed exclusively on chironomid larvae during spring but fed mostly on emerald shiners and perch during the summer months (Erickson and Lysack 1981). In this study the two most recognizable items in sauger stomachs were perch and shiners. A summer peak in sauger abundance may therefore be related to the known summer abundance of shiners and perch at Netley-Libau Marsh. Goldeye do not show strong food preferences although Corixids and other aquatic insects

make up the bulk of their food (Scott and Crossman 1973). The food of yellow perch is largely immature insects, larger invertebrates and fishes as well as the eggs and young of a wide variety of fishes. Both diets are consistent with extensive feeding use of environments like Netley-Libau Marsh.

Close agreement between fish community structure and the floodplain utilization concept suggests cyclical movements into and out of Netley-Libau Marsh. Based on movement pattern classification, the majority of abundant Netley-Libau Marsh species are seasonally migratory between deep and shallow waters. Netley-Libau Marsh itself does not provide extensive deepwater habitat so that Lake Winnipeg and the Red River mainstem are probably important components of the total habitat needs for these species. Disagreement between movement patterns based on the literature and observed abundance patterns suggest that more detailed study of local movement patterns may prove interesting. Bullhead, for instance, may exhibit movement patterns in Manitoba. Clarke et. al. (1980) found that black bullheads *(Ictalurus melas)*, a species similar in biology to the brown bullhead, tagged in the Red River at Winnipeg were recaptured as far away as Morris, Manitoba to the south and Lockport to the north. They hypothesized that black bullheads moved upstream past Winnipeg to spawn in late May to early July and began to return downstream to unknown wintering areas from July onwards. Brown bullhead at Netley-Libau Marsh exhibited a similar abundance pattern so that this species may not be as sedentary as the general literature indicates. Walleye tagging showed that interchange between the three

water bodies occurs and may be seasonal in nature. Walleyes tagged in Netley-Libau Marsh during spring were recaptured in the Red River and Lake Winnipeg during fall and winter.

Population dynamics information provides indirect support of seasonal interchange between the marsh and adjacent waters. Since fishing at Netley-Libau Marsh is limited, fish populations, if restricted only to the marsh, should be free from exploitation. Netley-Libau Marsh saugers had population statistics approximating those of exploited Lake Winnipeg south basin saugers (Lysack 1980, 1981, 1982) (Appendix N). Age range, mortality and survival, length-weight relationships and growth in length were similar to estimates for Lake Winnipeg's south basin and channel stocks. A lower modal age and relatively young age composition for Netley-Libau Marsh saugers are attributable to the use of small mesh sizes which are not included for commercial monitoring on Lake Winnipeg. Sauger appear to be recruited to the commercial fishery at about 5+ years. The Netley-Libau Marsh catch curve shows higher survival for pre-recruitment age groups than for 5+ and older age groups whose survival rate is close to that of exploited south basin saugers. The increase in mortality rate among older age groups for Netley-Libau Marsh saugers is suggestive of fishing pressure which could only occur from the Red River sport fishery and Lake Winnipeg commercial fishery. A similar situation is evident for goldeye. Goldeye are known to grow as old as 15+ years so the longevity of Netley-Libau Marsh goldeye (oldest sampled age 5+) does not appear to be very good. Mortality was high. Asymptotic size was much lower than the maximum recorded length from other Canadian locations ($\sim$ 437mm, Sandy L., Ontario; Scott and Crossman 1973). Growth rates and

age specific lengths and weights suggest rapid growth similar to the fastest reported growth in Canadian waters. The Lake Winnipeg commercial fishery for goldeye, once the largest in Canada, is known to have collapsed around 1938 (Scott and Crossman 1973). This collapse may have been attributable in part to fishing pressure. Goldeye of almost any size become entangled by their teeth in gillnets of various mesh sizes (Kennedy and Sprules 1967). A minimum mesh size of 9.5 cm is more or less optimum. The minimum legal mesh size on Lake Winnipeg's south basin is 7.6 cm. This type of fishing regime could be expected to apply heavy fishing pressure on goldeye stocks resulting in population statistics similar to those observed in the Netley-Libau Marsh goldeye population. Northern pike from Netley-Libau Marsh showed a good range in age. The maximum observed age (10+) fitted the life expectancy range for fast growing southern Canadian populations (10-12+). Pike showed the highest survivorship of the three species in this study. Growth in length and weight indicated good condition. The growth in length with age of Netley-Libau Marsh pike is difficult to compare to general growth since growth is highly variable in Canada. In southern Canada the age of maturity is 3-4 years for females and 2-3 years for males. Probable spawning age groups of pike were therefore well represented at Netley-Libau Marsh. These population statistics suggest that Netley-Libau Marsh pike do not suffer from exploitation to the same extent as local goldeye and sauger populations. As shown earlier, pike are closely associated with Netley-Libau Marsh for a considerable portion of the year, certainly longer than either sauger or goldeye. They could there-

fore be expected to escape more fishing pressure than the other two species and this seems to be reflected by their population dynamics.

Given the range of values that a floodplain or shallow water fish community may take, the Netley-Libau Marsh fish community is in reasonably good condition. A variety of species use the marsh. The level of use is fairly extensive, in that fish are abundant, while the type of use (i.e. spawning, nursery and feeding grounds) corresponds to that expected for a productive shallow water zone. From this point of view, Lake Winnipeg regulation does not seem to have produced gross negative effects on the fish community to date. Similarly, other anthropogenic activities (i.e. peripheral dyking, upstream damming) which have been in place over a considerably longer period have not reduced fish use to an extreme degree. This does not imply that these activities are benign since there are concerns about their negative effects on fish communities. The pre-regulation and pre-settlement fish communities of Netley-Libau Marsh are unknown making all but the most marked effects unmeasurable. As of 1980-1981, however, the Netley-Libau Marsh, based on its fish community, appears to be a viable fish habitat.

ASSOCIATED FISHERIES

Since Netley-Libau Marsh is not extensively exploited by direct fishing its primary fisheries value is its use as a spawning, nursery and feeding ground by species which are exploited elsewhere and species which are important forage for exploited species. Fish species using the Netley-Libau Marsh are prominent features of the major fisheries

which take place in Lake Winnipeg and the Red River. Areas like Netley-Libau Marsh, especially when they have high production potential, must therefore be considered as an important part of the habitat necessary for continued fishing success.

Sauger are the most economically important species found in abundance at Netley-Libau Marsh. According to Scott and Crossman (1973) Manitoba is the sole major Canadian producer of this valuable commercial and sport fish. The Lake Winnipeg annual catch of 1.3 million kg represents 87% of Manitoba's sauger production. The Red River produces more trophy size individuals than any other Manitoba waters. The sauger feeding migration into Netley-Libau Marsh involves all the fisheries values associated with shallow water zones. Yellow perch, a primary sauger prey, probably use the marsh extensively for spawning thereby creating a concentrated food source in terms of young-of-year fish which are preyed upon by sauger. There may also be a similar predator-prey relationship between sauger and emerald shiners although details of the relationship are unknown. It is a principle of predation that piscivorous predators may consume more fish than fisheries remove (Campbell 1979). The portion of the Lake Winnipeg sauger population that is harvested therefore, alone, requires a food supply greater than 1.3 million kg. From this point of view areas like Netley-Libau Marsh which have a high potential for producing this food supply are important in terms of fishing success. This relationship suggests how declines in fisheries production, such as Welcomme's (1979) Missouri River example may occur when floodplain habitat is lost.

Floodplain losses can result in twofold fish population declines. Some species have a potential to decline directly as a result of lost spawning habitat (eg. yellow perch) while others (eg. sauger) have a potential to decline indirectly as the result of a decline in the prey population.

Aside from its role as prey for sauger, the yellow perch is of economic value in its own right. Commercially, 78% of Manitoba's 49,496 kg annual yellow perch production is caught in Lake Winnipeg. Yellow perch currently have a higher value per kilogram than the better known walleye and sauger (May 1, 1983 FFMC price list). The perch is also an important recreational fish although the Red River does not appear to be a major producer of larger size fish.

Spottail and emerald shiners have been called the most important forage cyprinids in Canadian lakes (Scott and Crossman 1973). This importance is the result of their value as a food item for commercially and recreationally valuable fishes as well as their value as bait. As a habitat used by emerald shiners, the Netley-Libau Marsh is therefore valuable to the Red River bait fishery.

Northern pike represent the fourth largest commercial fish catch in Manitoba annually. Lake Winnipeg produces 17% of Manitoba's annual pike production. Although the pike is one of the most sought after sport species the Red River does not appear to be a major producer of trophy size individuals. Since the northern pike is a phytophilous spawner, areas like Netley-Libau Marsh are vital to the maintenance of pike populations in the Lake Winnipeg area.

The goldeye represents a species of historical importance in the Lake Winnipeg-Red River area. The goldeye occurs only in North America (Scott and Crossman 1973). Consumer demand has regularly exceeded supply since 1930 (Scott and Crossman 1973). At one time, Canadian production was predominantly from Lake Winnipeg but a major catch has not been produced since 1938 (Scott and Crossman 1973). Lake Winnipeg still accounts for 9% of Manitoba's goldeye production but the amount caught is insignificant relative to historical catches (Scott and Crossman 1973). The Red River is the second most valuable water in the province for production of trophy size goldeye for angling (Table 13).

The other abundant Netley-Libau Marsh fishes have minor or potential fisheries values. The Lake Winnipeg catch of freshwater drum represents 97% of Manitoba's annual 9,506 kg drum harvest. The Red River is second among Manitoba waters in the production of trophy size freshwater drum. Bullheads have minor commercial value in Manitoba. The Red River produces the most trophy size bullheads in the province. Bullheads are traditionally unpopular in Manitoba due to their appearance. They are, however, delicious when cooked properly and have been found to be a very suitable pond culture species in the United States (Scott and Crossman 1973). Manitoba's Fisheries Branch at present includes bullheads in a public awareness program designed to increase use of underutilized sport species. Recently, markets have been found in the southern U.S. for live bullheads from Manitoba waters and the value and popularity of the species

to commercial fishermen is expected to increase sharply. There is therefore potential for increased use and greater fisheries value of bullheads in Manitoba. The carp is generally considered to be a nuisance fish. Carp, an introduced species,were first recorded in Manitoba from the Red River at Lockport in 1938 (Scott and Crossman 1973). McLeod and Moir (1944 a,b) felt that the rapid proliferation of carp in the Red River area and especially their presence in Netley-Libau Marsh was exaggerated and that carp represented a minimal threat to muskrat populations. Lake Winnipeg currently produces 19% of Manitoba's annual 298,008 kg commercial carp harvest. The Red River produces more master angler awards for carp than any other Manitoba waters. Since carp are phytophilous spawners and can be expected to make spawning runs into the Netley-Libau area there is potential for increased commercial carp fishing in the Netley-Libau area. Scott and Crossman (1973) have also pointed out that a positive aspect of carp introduction is the utilization of young carp as forage by predators such as northern pike. Northern pike in this study were noted to use young carp for food so that this positive aspect of the carp appears to be true in the Netley-Libau Marsh area.

MARSH DEVELOPMENT AND THE FISH RESOURCE

Developments of the type involving internal dyking for water control would lower the fisheries value of the Netley-Libau Marsh. The shallowness of the Netley-Libau Marsh makes it fragile with respect to flood control style developments due to seasonal variation in ability

to adequately support fish life. Isolation of marsh areas, as suggested by the Lake Winnipeg Marshes Working Group (1977) would prevent use of a high trophic status area by migratory Red River and Lake Winnipeg fishes. Occasional invasions which may occur, perhaps due to back flooding or exceptionally high flood stages, would represent a drain on invading populations since an extinction pressure would be created in compartmentalized areas in the form of mortality due to winterkill (Mahon and Balon 1977). Stabilization of water levels also represents the second and to some extent the third cutting points of Welcomme's (1979) typical development sequence which, in general, associates increasing floodplain regulation with decreasing fisheries value.

In terms of advised planning for floodplain areas these types of developments must be approached with extreme caution (Welcomme 1979). This is true of the Netley-Libau area based on the results of this study. Economically important migratory fishes use Netley-Libau Marsh, and the fisheries which exploit them are major Manitoba fisheries. Developments designed to increase waterfowl production should therefore attempt to allow for existing fish use patterns.

Current fish husbandry practices in Manitoba would only be partially applicable to the Netley-Libau area. Stocking with walleye, a mesotherm, for instance may be feasible given Netley-Libau's high trophic status and acceptable open water temperatures regime. Ideally this practice would be used to augment existing fish use and utilize more fully Netley-Libau Marsh's high trophic status. It would however

be a poor alternative if used to replace existing multispecies fisheries values especially production of forage fish. Existing aquaculture in Manitoba is currently restricted to put and take rainbow trout *(Salmo gairdneri)* farming. The rainbow trout is a stenotherm. As previously shown the temperature regime at Netley-Libau Marsh is not favourable to stenotherms. Also, the existing technology for trout farming is such that it is not advisable as a business venture since costs tend to exceed profit (Cauvin and Thompson 1977). Clearly, neither fish husbandry nor aquaculture in Manitoba are sufficiently well developed to be able to fully mitigate the effects of poorly planned developments in areas like Netley-Libau Marsh.

SUMMARY

The foregoing discussion stresses the need to consider the Netley-Libau Marsh as a unique and productive component of the total fish habitat in the Lake Winnipeg-Red River area. The foregoing literature review indicates that modifications to floodplain-wetland habitats which restrict fish access, change the hydraulic regime, or otherwise cause a reduction in fish production cause declines in the value of associated fisheries. Habitat modifications to Netley-Libau Marsh which prevent effective spawning, nursery and feeding use by fishes such as pike, shiners, perch, sauger and goldeye must therefore be avoided in order to protect the surrounding sport, bait and commercial fisheries. For this reason, fisheries planning

for Netley-Libau Marsh should attempt to maintain it in as unmodified a condition as possible.

CONCLUSIONS

Given the available fish resource data on Netley-Libau Marsh it is concluded that:

1. The Netley-Libau Marsh is morphologically a unique feature of the Lake Winnipeg area. The Netley-Libau Marsh is, at present, slightly modified but still provides seasonally excellent conditions for utilization and production by fish.

2. The Netley-Libau Marsh fish community is probably derived primarily as a result of open water utilization of the Marsh by Red River and Lake Winnipeg fish populations. The fish community is both diverse and abundant during the open water season. Fish of scientific as well as economic value use the Netley-Libau Marsh as a spawning, nursery and feeding area. The most valuable abundant fish in the Netley-Libau Marsh fish community are yellow perch, shiners, sauger, goldeye and northern pike. These fish are valuable due to their commercial, sport and/or historical fisheries value.

3. There is little fishing in the Netley-Libau Marsh proper. Fisheries in the Red River and Lake Winnipeg are among the most important of Manitoba's fisheries and are associated with the Netley-Libau Marsh since important exploited species utilize the Netley-Libau area.

4. The existing wildlife development concept is contrary to advised fisheries planning for areas like Netley-Libau Marsh based on the scientific literature. Fisheries planning for the Netley-Libau Marsh should attempt to maintain it in as unmodified a condition as possible with respect to the natural use pattern of fish populations.

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APPENDIX A

Site Maps Showing Sampling Locations

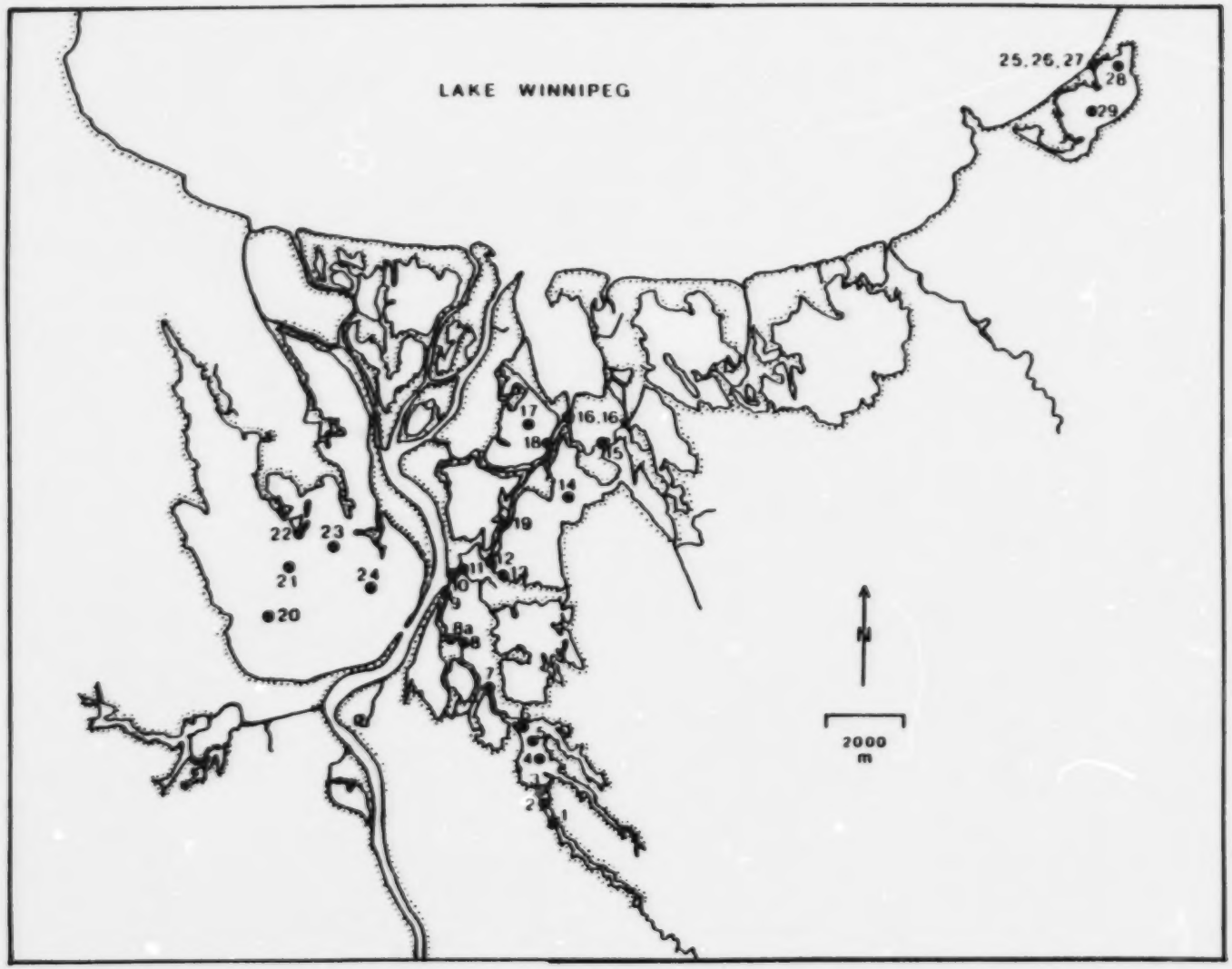

Fig. A.1. Locations of ice thickness water depth, water temperature and dissolved oxygen measurements at Netley-Libau Marsh, winter 1980-1981. Goldeye Lake and Goldeye Creek sampling stations are shown in Fig. 5 of the text.

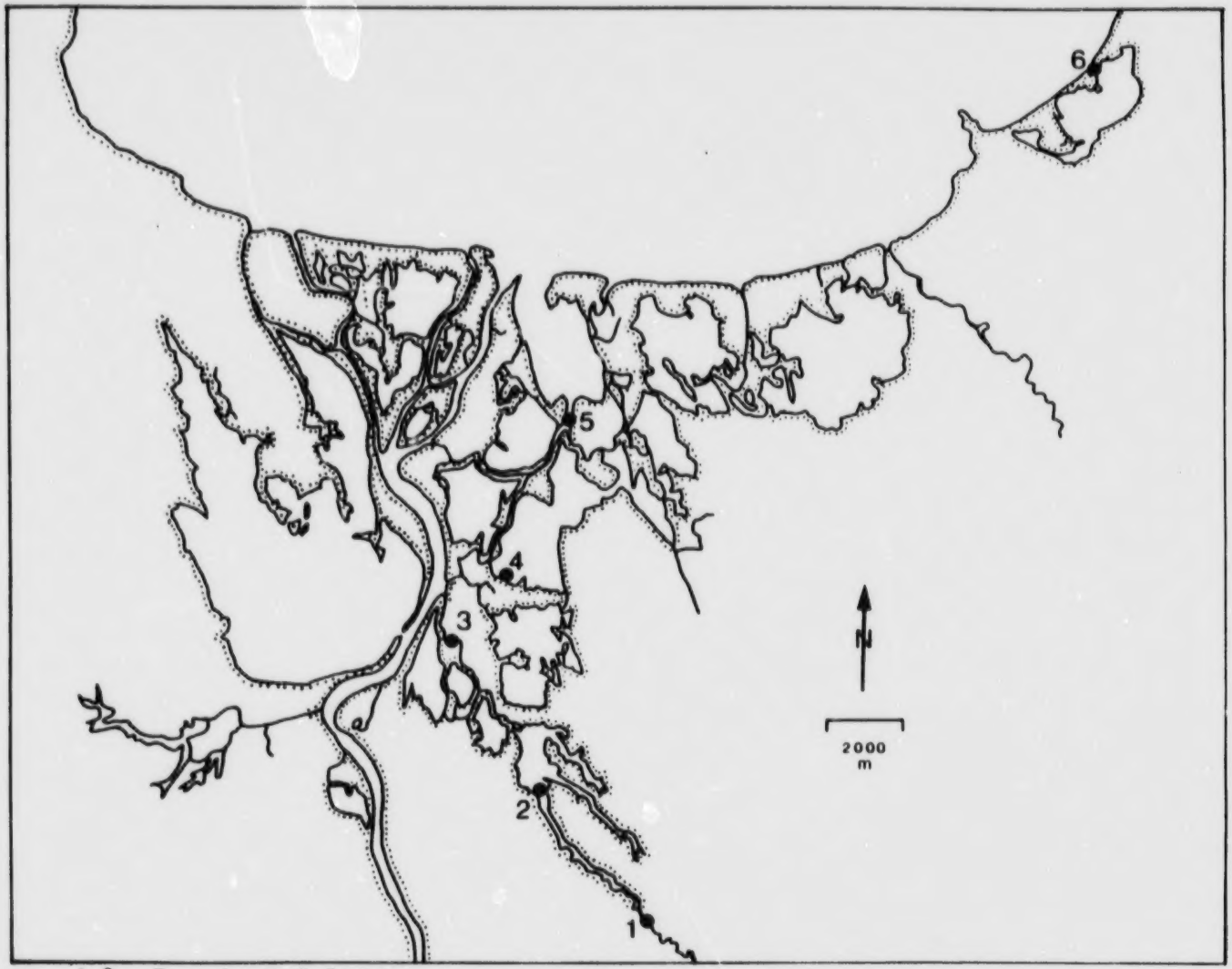

Fig. A.2. Experimental fishing, open water dissolved oxygen, and open water chemistry stations at Netley-Libau Marsh, 1981. 1. Devil Creek, April 10-17. 2. Upper Devil Lake April 22-August 27. 3. Devil Creek, March 16. 4. Lower Devil Lake, May 14-October 28. 5. Pruden Bay channel, March 16. 6. Beaconia Lake, May 12-August 21. Open water dissolved oxygen and water chemistry samples were taken from stations 2,4 and 6.

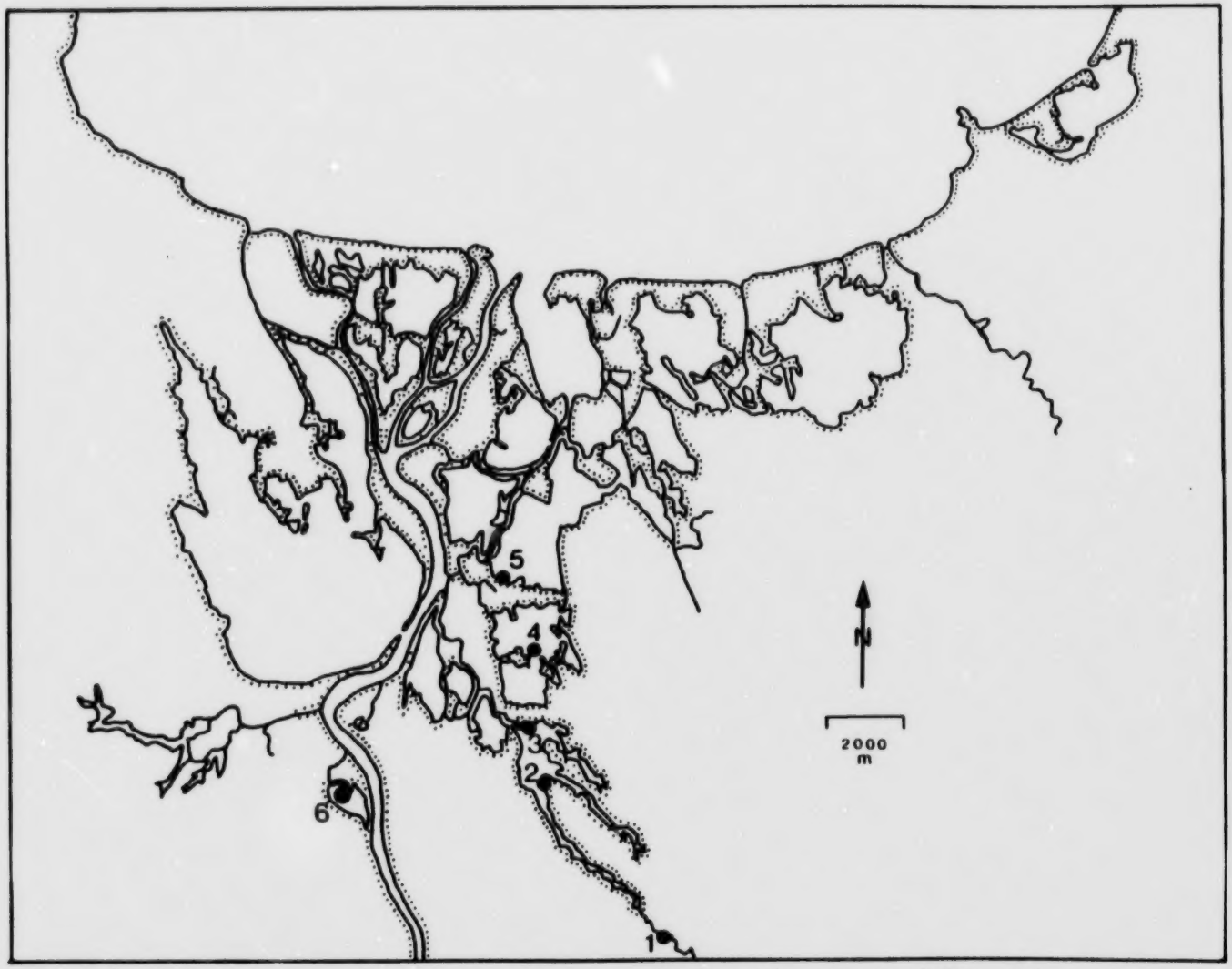

Fig. A.3. Fyke netting and rotenone stations at Netley-Libau Marsh, 1980. Fyke netting stations were: 1. Devil Creek, April 18-May 9. 2. Upper Devil Lake, August 13-19. 3. Upper Devil Lake August 20. 4. Morrison Lake, September 4. 5. Lower Devil Lake August 29. 6. Goldeye Lake September 12. One rotenone sample was taken at station 5.

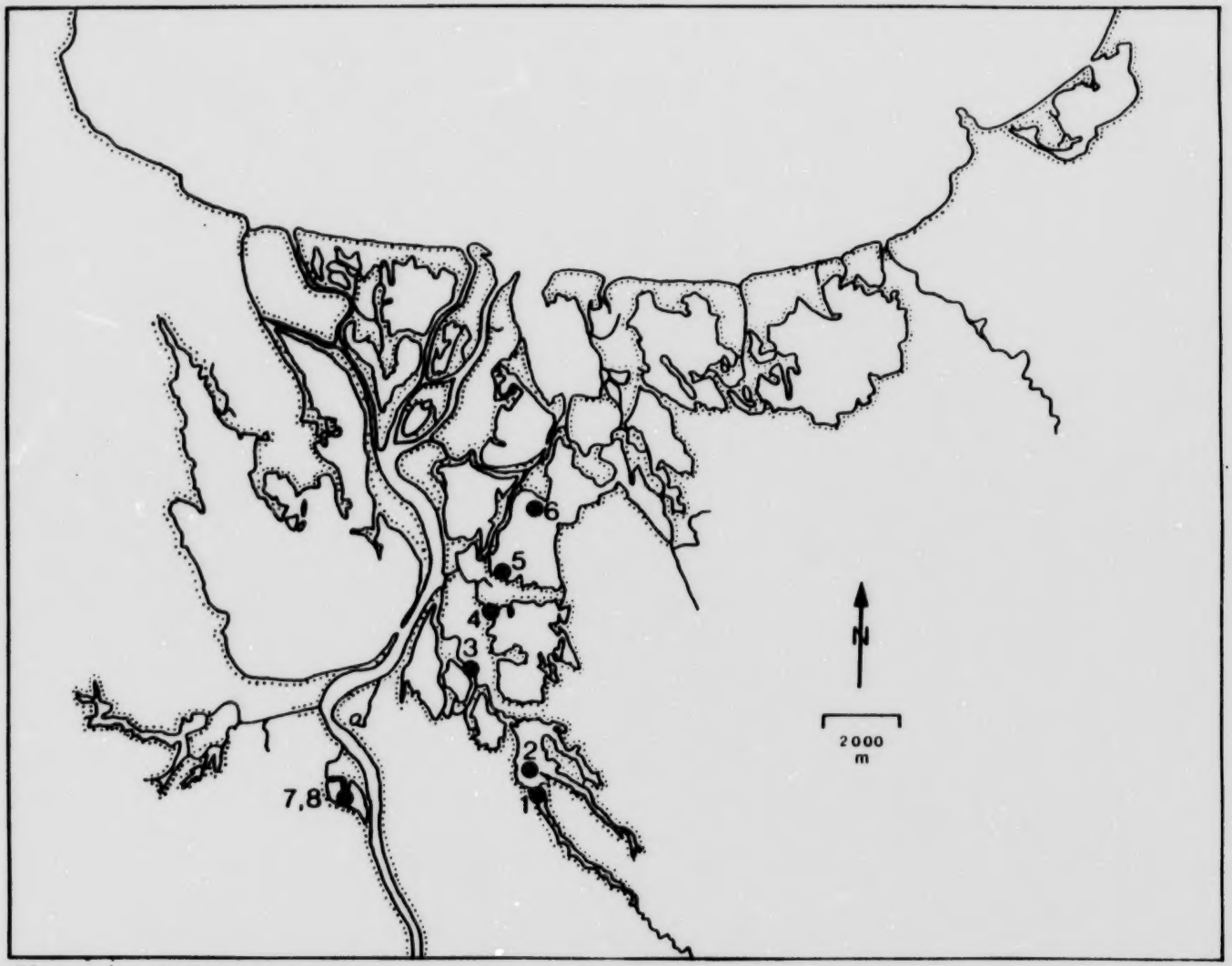

Fig. A.4. Gillnetting stations at Netley-Libau Marsh, open water 1980. 1,2 Upper Devil Aug. 15,21. 3. Devil Creek, Aug. 22. 4, Morrison Lake, Sept. 4. 5,6 Lower Devil Lake Aug. 27-28. 7,8 Goldeye Lake, Sept. 19, Oct. 23.

APPENDIX B

Flow rate data for Devils Creek

Table B.1. Streamflow information for Devils Creek near Libau.

Year	Mean monthly discharge ($m^3 sec^{-1}$)											Total discharge (dam^3)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1971	-	-	0.08	7.21	0.56	0.32	0.20	0.04	0.15	0.22	-	-	22,900
1972	-	-	0.01	3.49	0.18	0.09	0.04	0.05	0.03	0.06	-	-	10,300
1973	-	-	1.23	0.25	0.07	3.42	0.27	0.09	0.31	0.59	-	-	16,300
1974	-	-	0.02	10.10	5.55	0.44	0.08	0.06	0.07	0.06	-	-	42,900
1975	-	-	0.02	2.63	0.36	2.47	0.52	0.10	0.05	0.08	-	-	16,200
1976	-	-	0.00	4.02	0.16	1.07	0.11	0.04	0.04	0.03	-	-	14,200
1977	-	-	0.09	0.41	0.07	0.09	0.11	0.08	1.37	0.32	-	-	6,660
1978	-	-	0.00	6.56	0.89	0.36	0.70	0.06	0.05	0.06	-	-	22,700
1979	-	-	0.00	7.82	2.14	1.28	0.10	0.06	0.13	0.06	-	-	30,200
Mean[1]	-	-	0.16	4.72	1.11	1.06	0.24	0.07	0.24	0.17	-	-	20,300
1980[2]	-	-	0.00	2.90	0.10	0.04	0.02	0.02	0.03	0.03	-	-	8,180
1981[2]	-	-	0.29	0.08	0.07	0.05	0.03	0.03	0.02	0.10	-	-	1,780

[1] 1971-1979 data from: Environment Canada 1979. Historical Streamflow Summary, Manitoba.

[2] 1980-1981 provisional data courtesy of Water Resources Division Manitoba. Pers. comm. June 21, 1982.

APPENDIX C

Depth, Ice Thickness Temperature and Oxygen Measurements

APPENDIX C

Depth, Temperature, Ice Thickness and Oxygen Measurements

1. Ice thickness, water depth, water temperature and dissolved oxygen measurements from Netley-Libau Marsh, winter 1980-1981.

2. Depth measurements of three gillnetting stations, 1981.

3. Open water oxygen measurements from Netley-Libau Marsh.

4. Summary of dissolved oxygen measurements from Netley-Libau Marsh, 1980-1981.

5. Composite water temperature record for Netley-Libau Marsh, 1980-1981.

6. Results of paired t-tests for comparison of surface and bottom temperatures and dissolved oxygen concentration.

Table C.1. Winter 1980/81 oxygen testing results from various areas in the Netley-Libau Marsh.

Site Description	Date	STN. #	Map. Ref. Code[1]	Water Depth m	Ice m	Snow m	Water Temp °C	O_2 conc. mg/l	O_2 conc. % sat.	Comments
Devil Creek	Feb. 24/81	1	579.5/701	0.50	1.00	0.00	2.50	20.4	153	- Corixids at hole
		2	577/707	0.50	0.75	0.00	2.50	23.5	177	- Corixids at hole
		3	576.5/710	0.75	0.75	0.00	2.50	20.4	153	
Upper Devil Lake		4	576/718	0.00	1.75	0.08		FB[2]		
Upper Devil Lake		5	574/722	0.00	1.00	0.00		FB[2]		
Devil Creek		6	571.5/726	0.75	0.75	0.00	0.50	34.1	244	
		7	563/735	0.87	1.63	0.00	1.25	29.7	217	
		8	556/748	3.00	0.75	0.00	2.00	21.5	159	
	Mar. 13/81	8a	552/748	1.50	1.00	0.00	2.00	24.5	181	
	Mar. 16/81	8a	552/748	---no data---			2.50	18.3	138	- sampled from bottom using Kemmerer
		8a	552/748	---no data---			2.50	22.4	168	- standard collection technique
	Feb. 24/81	9	551/761	3.00	1.00	0.00	2.00	8.8	65	
unnamed Marsh channel		10	552.5/765	3.00	0.75	0.00	1.50	8.2	60	
		11	555/770	2.75	0.00	0.00	1.50	8.9	65	- water bubbling through holes in ice
channel at L. Dev. Lake		12	562.5/770	2.50	1.00	0.00	2.00	26.8	199	- Corixids at hole
channel in L. Dev. Lake		13	565/765	0.25	0.75	0.00	0.50	19.9	142	
Lower Devil Lake		14	582/784.5	0.00	0.88	0.00		FB		
unnamed Marsh channel		15	591/799	0.25	0.75	0.00	1.00	20.1	146	
channel at S. end Pruden B.		16	582/805	2.75	1.00	0.00	2.00	28.3	210	
	Mar. 13/81	16a	582/805	1.60	0.90	0.00	2.50	22.8	171	
	Mar. 16/81	16a	582/805	---no data---			3.00	7.2	55	- sampled from bottom using Kemmerer
		16a	582/805	---no data---			3.00	28.4	217	- standard collection technique
Ramsay Lake	Feb. 24/81	17	571/803	0.00	0.63	0.00		FB		
channel S. end Ramsay		18	577.5/793	0.22	0.78	0.00	<0.50	20.8	149	- Corixids at hole
unnamed Marsh channel	Feb. 24/81	19	565/776	0.50	0.75	0.00	1.50	25.0	182	- Corixids at hole
Netley Lake	Feb. 25/81	20	506/754	<0.05	0.95	0.00	1.00	12.8	93	- near pressure ridge
		21	511/767	0.08	0.92	0.00	1.00	24.7	179	
		22	513/776	0.00	0.63	0.00		FB		
		23	522.5/772	0.04	0.75	0.00		NS		
		24	532/762	0.00	0.75	0.00		FB		
Beaconia Lake	Feb. 26/81	25	715.5/898.5	0.04	0.26	0.00	0.50	8.5	61	- sand bottom channel at beach ridge
		26	716.5/898	<0.04	0.70	0.00	0.25	13.2	94	- water leaking in at sides of hole
		27	717.5/898	0.00	0.50	0.00		FB		- marsh end of channel water seepage
		28	723/899.5	<0.04	0.90	0.00	0.50	3.2	23	- Corixids in hole
		29	716/886.5	<0.04	0.70	0.00		NS		- some water leaking in

[1] UTM grid reference to nearest 100 m on map 62-1/7 Edition 2 MCE series A 743 scale 1:50,000

[2] FB = frozen to bottm, NS = no sample

Table C.2. Winter 1980-1981 oxygen levels in Goldeye Lake and Goldeye Creek, Netley-Libau Marsh[2].

Area	Date	Station number	Water Depth (m)	Ice Thickness (m)	Snow Depth (m)	Water Temp °C	O_2 level mg/l^{-1}	O_2 level % saturation
Goldeye Creek	Jan. 28, 1981	1	0.15	1.00	0.00	0.00	6.1	43
		2	0.15	1.00	0.08	0.00	4.3	30
		3	0.36	0.91	0.04	0.00	1.1	8
		4	0.61	0.91	0.04	0.50	<0.1	<0.7
		5	0.30	0.91	0.05	0.50	<0.1	<0.7
		6	0.00	0.91	0.05	FB[1]	-	-
Goldeye Lake	Jan. 28, 1981	7	0.00	0.36	0.00	FB	-	-
		8	0.00	0.56	0.00	FB	-	-
		9	0.00	0.61	0.00	FB	-	-
		10	0.00	0.76	0.00	FB	-	-
		11	0.00	0.76	0.00	FB	-	-
		12	0.00	0.61	0.00	FB	-	-
Goldeye Creek	Feb. 25, 1981	2	0.11	0.69	0.00	1.00	8.7	63
		3	0.50	0.75	0.00	1.00	2.7	20
		3a	0.05	0.75	0.00	0.50	0.7	5
		3b	0.05	0.75	0.00	0.50	<0.1	<0.7
		3c	0.15	0.65	0.00	0.00	0.5	4
		3d	0.08	0.72	0.00	0.25	<0.1	<0.7

[1] FB = frozen to bottom

[2] Station locations are shown in Fig. 10 of the text.

Table C.3. Depth measurements at gillnet set locations[1] in three Netley-Libau Marsh lakes, 1981[2].

Upper Devil Lake		Lower Devil Lake		Beaconia Lake	
date	depths (m)	date	depths (m)	date	depths (m)
May 7	1.0-0.8	May 5	0.3-0.6	May 11	0.8-0.8
June 1	1.2-1.0	May 13	1.3-1.3	May 25	0.6-1.0
June 10	1.3-1.3	June 8	1.3-1.3	June 3	0.8-1.0
June 11	1.2-1.2	June 29	1.0-1.0	June 4	0.5-0.7
June 22	1.0-1.0	July 8	1.0-1.0	June 15	1.0-1.1
July 6	1.3-1.0	July 20	1.0-1.0	June 17	0.9-1.0
July 14	1.0-1.3	August 4	1.3-1.3	June 24	0.8-1.0
July 27	1.3-1.0	August 25	1.2-1.2	July 2	0.9-1.5
August 11	1.5-1.0			July 5	0.6-1.0
August 18	1.5-1.5			July 23	0.6-1.5
				July 29	0.5-1.0
				August 6	1.3-1.3
				August 9	1.5-1.5
				August 20	1.3-1.3
No. measurements	20		15		28
mean depth (m)	1.17		1.06		0.99
std. deviation (m)	20		0.29		0.32
range (m)	0.8-1.5(0.70m)		0.3-1.3(1.00m)		0.5-1.5(1.00m)

[1] depths were measured at each end of the gillnet gang

[2] gillnetting locations are shown in Fig. 4.

Table C.4. Open water dissolved oxygen measurements from Netley-Libau Marsh, 1981[1].

Area	Date	water depth (m)	water temperature °C		O_2 concentration mg/l^{-1}			% saturation O_2		
			surface	bottom	surface		bottom	surface		bottom
Upper Devil Lake	June 22, 1981	1.0	18.0	17.5	-	14.2	-	-	152	-
	July 6, 1981	1.0-1.3	23.5	-	-	12.4	-	-	149	-
	July 27, 1981	1.0-1.3	20.0	20.0	9.5		9.2	107		103
	Aug. 18, 1981	1.5	17.5	17.5	8.3		7.9	89		85
Lower Devil Lake	June 17, 1981	0.9-1.0	17.5	17.5	-	10.5	-	-	112	-
	June 29, 1981	1.0	20.0	20.0	-	13.7	-	-	154	-
	July 22, 1981	1.0	22.0	-	-	13.9	-	-	163	-
	Aug. 10, 1981	1.5	19.0	19.0	11.4		10.8	126		120
Beaconia Lake	June 16, 1981	1.0-1.1	17.0	17.0	-	8.5		-	90	-
	June 25, 1981	0.8-1.0	17.5	17.5	9.3		9.0	100		97
	July 24, 1981	0.6-1.5	21.0	-	-	8.4	-	-	96	-
	Aug. 20, 1981	1.3	18.5	18.5	7.9		7.5	87	87	82

Total Measurements = 17
Mean = 112%
Range = 85-163%
Standard Deviation = 27

Table C.5. Summary of dissolved oxygen measurements from Netley-Libau Marsh, 1980-1981.

Season	No. measurements	Dissolved oxygen (% saturation) mean	std. deviation	range	(total range)
winter 1980-81 (all samples)	37	104.78	77.60	<0.7-244	(243.30)
winter 1980-81 (corrected[1]	20	41.49	38.83	<0.7-138	(137.30)
open water, 1981	17	112.00	27.00	85-163	(78.00)

[1]The corrected data set included measurements less than saturation and measurements from samples collected with a Kemmerer sampler.

Table C.6. Composite water temperature record for Netley-Libau Marsh, 1980-1981.

Time	week	No. measurements	temperature (^{o}C) mean	standard deviation	range
winter ice conditions	Jan. 25-31/81	12	0.08	0.19	0.00-0.50
	Feb. 22-28/81	34	0.90	0.82	0.00-2.50
	Mar. 8-14/81	2	2.25	0.35	2.00-2.50
	Mar. 15-21/81	4	2.75	0.29	2.50-3.00
Open water conditions	April 13-19/80	2	11.30	1.13	10.50-12.10
	April 20-26/80	7	11.50	1.71	10.00-15.00
	April 28-30/80	3	16.83	3.18	15.00-20.50
	May 1-3/80	3	18.67	0.58	18.00-19.00
	May 5-9/80	5	12.70	2.86	10.00-17.00
	April 5-11/81	6	4.75	3.06	0.00-8.00
	April 12-18/81	4	6.75	3.86	3.00-11.00
	April 19-25/81	3	5.00	0.00	-
	April 26-30/81	4	9.50	1.00	8.00-10.00
	May 1-2/81	1	11.00	-	-
	May 3-9/81	1	0.00	-	-
	May 10-16/81	4	12.75	6.55	3.00-17.00
	May 17-23/81	2	17.00	1.41	16.00-18.00
	May 24-30/81	7	17.14	2.04	14.00-21.00
	June 1-6/81	4	17.00	3.56	14.00-21.00
	June 7-13/81	4	18.00	0.00	-
	June 14-20/81	4	16.25	1.71	14.00-18.00
	June 21-27/81	4	18.50	1.00	18.00-20.00
	June 28-30/81	2	19.00	1.41	18.00-20.00
	July 5-11/81	4	22.25	1.71	20.00-24.00
	July 12-18/81	5	23.20	0.45	23.00-24.00
	July 19-25/81	5	21.40	1.14	20.00-23.00
	July 26-31/81	4	20.00	-	-
	Aug. 2-8/81	4	22.25	1.26	21.00-24.00
	Aug. 9-15/81	4	20.50	1.73	19.00-22.00
	Aug. 16-22/81	4	19.00	0.82	18.00-20.00
	Aug. 23-29/81	2	23.50	0.71	23.00-24.00
	Oct. 25-31/81	1	1.00	-	-

Table C.7. Results of t-tests for paired comparisons of surface and bottom measurements of water temperature and dissolved oxygen concentration from Netley-Libau Marsh, 1981.

comparison	No. pairs	Means		$\bar{D}$	$S_{\bar{D}}$	t	d.f.
		Surface	Bottom				
water temp. (^{o}C)	9	19.0	18.9	0.06	0.0557	1.08	8
0_2 conc'n ($mg.l^{-1}$)	5	9.3	8.9	0.4	0.06	6.7	4
0_2 conc'n (% sat'n)	5	102	97	4	0.4	10	4

APPENDIX D

Water Chemistry Data

Table D.1. Water chemistry data for Upper Devil Lake, Netley-Libau Marsh, 1981.

Parameter	Sample date				Mean
	June 22	July 6	July 27	August 18	
Conductivity (µmho/cm)	385	720	360	580	511
Total dissolved solids (mg/l)	400	500	390	480	443
Total suspended solids (mg/l)	50	52	115	15	58
pH	9.1	8.9	8.6	8.7	8.8
Turbidity (Nephelometric turbidity units)	30	75	50	25	45
Colour - true	20	3	20	30	18
Alkalinity ($CaCO_3$) (mg/l)	168	193	160	203	181
Alkalinity (HCO_3) (mg/l)	205	196	182	223	202
Alkalinity (OH^3) (mg/l)	0.0	0.0	0.0	0.0	0.0
Alkalinity (CO_3) (mg/l)	0.0	19.2	7.2	12.0	9.6
Organic carbon - total (mg/l)	25	23	25	24	24
Organic carbon - dissolved (mg/l)	15.5	17.0	15.0	15.0	15.6
Phosphorus - total (mg/l)	0.30	0.32	0.40	0.40	0.36
Phosphorus - dissolved (mg/l)	0.06	-	1.20	0.30	0.50
Nitrogen - total (mg/l)	1.9	2.1	2.7	2.2	2.2
Nitrogen - dissolved (mg/l)	1.1	0.9	1.1	1.1	1.05
Nitrate - Nitrite - dissolved (mg/l)	<0.01	0.46	0.05	<0.01	0.13
Sulphate - soluble (mg/l)	88	94	92	93	92
Chloride - soluble (mg/l)	34	76	55	44	52
Sodium - extractable (mg/l)	36	60	53	43	48
Calcium - extractable (mg/l)	33	60	53	58	51
Potassium - extractable (mg/l)	7.7	11.0	7.4	7.7	8.5
Magnesium - extractable (mg/l)	23	33	30	30	29
Manganese - extractable (mg/l)	0.03	0.13	0.23	0.18	0.14
Iron - extractable (mg/l)	0.05	0.40	0.58	0.42	0.36
Silica - soluble reactive (mg/l)	2.0	6.4	8.6	-	5.7
Chlorophyll - a (µg/l)	72.8	72.2	96.0	63.6	76.2

Table D.2. Water chemistry data for Lower Devil Lake, Netley-Libau Marsh, 1981.

Parameter	Sample date				Mean
	June 17	June 29	July 22	August 10	
Conductivity (µmho/cm)	480	420	480	550	483
Total dissolved solids (mg/l)	417	269	426	405	379
Total suspended solids (mg/l)	101	121	8	55	71
pH	9.0	9.2	9.1	8.7	9.0
Turbidity (Nephelometric turbidity units)	40	50	30	20	35
Colour - true	20	20	30	35	26
Alkalinity ($CaCO_3$) (mg/l)	168	121	121	171	145
Alkalinity (HCO_3) (mg/l)	168.0	148.0	116.0	53.7	121.4
Alkalinity (CO_3) (mg/l)	18.0	0.0	13.0	3.6	8.7
Alkalinity (OH) (mg/l)	0.0	0.0	0.0	0.0	0.0
Organic carbon - total (mg/l)	25.0	25.0	29.5	20.5	25.0
Organic carbon - dissolved (mg/l)	15.0	15.0	16.5	15.0	15.4
Phosphorus - total (mg/l)	0.30	0.30	0.30	0.24	0.29
Phosphorus - dissolved (mg/l)	0.05	-	0.10	0.08	0.08
Nitrogen - total (mg/l)	2.5	2.3	3.3	1.8	2.5
Nitrogen - dissolved (mg/l)	1.5	1.2	1.2	1.0	1.2
Nitrate - Nitrite - dissolved (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01
Sulphate - soluble (mg/l)	97.0	86.5	82.5	77.0	85.8
Chloride - soluble (mg/l)	44	41	53	44	46
Sodium - extractable (mg/l)	40	42	47	44	43
Calcium - extractable (mg/l)	40	33	38	50	40
Potassium - extractable (mg/l)	8.6	9.3	7.4	7.0	8.1
Magnesium - extractable (mg/l)	23	23	25	28	25
Manganese - extractable (mg/l)	0.06	0.23	0.22	0.13	0.16
Iron - extractable (mg/l)	0.05	0.57	0.70	0.45	0.44
Silica - soluble reactive (mg/l)	3.6	3.7	3.7	12.6	5.9
Chlorophyll - a (µg/l)	-	74.8	153.0	50.0	92.6

Table D.3. Water chemistry data for Beaconia Lake, Netley-Libau Marsh, 1981.

Parameter	Sample date				Mean
	June 16	June 25	July 24	August 20	
Conductivity (µmho/cm)	285	365	285	280	304
Total dissolved solids (mg/l)	230	253	260	215	240
Total suspended solids (mg/l)	36	45	180	6	66.8
pH	8.4	8.4	9.5	8.9	8.8
Turbidity (Nephelometric turbidity units)	20	20	35	5	20
Colour - true	15	15	15	20	16.3
Alkalinity ($CaCO_3$) (mg/l)	115	126	101	112	114
Alkalinity (HCO_3) (mg/l)	128.0	147.0	76.4	122.0	118.0
Alkalinity (CO_3) (mg/l)	6.0	3.1	23.3	7.2	9.9
Alkalinity (OH) (mg/l)	0.0	0.0	0.0	0.0	0.0
Organic carbon - total (mg/l)	15.0	15.0	27.0	19.5	19.1
Organic carbon - dissolved (mg/l)	13.5	11.0	14.0	17.0	13.9
Phosphorus - total (mg/l)	0.1	0.2	0.4	0.2	0.2
Phosphorus - dissolved (mg/l)	-	0.04	0.10	-	0.07
Nitrogen - total (mg/l)	0.7	1.0	1.8	1.0	1.1
Nitrate - Nitrite - dissolved (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrogen - dissolved (mg/l)	0.6	0.9	1.3	0.6	0.9
Sulphate - soluble (mg/l)	44.0	51.0	46.5	31.0	43.1
Chloride - soluble (mg/l)	19	23	24	16	21
Sodium - extractable (mg/l)	20	28	20	15	21
Calcium - extractable (mg/l)	33	35	45	35	37
Potassium - extractable (mg/l)	5.0	4.8	4.4	3.4	4.4
Magnesium - extractable (mg/l)	10	18	23	15	17
Manganese - extractable (mg/l)	0.02	0.12	0.29	0.08	0.13
Iron - extractable (mg/l)	0.10	0.45	1.20	0.16	0.48
Silica - soluble reactive (mg/l)	0.7	1.2	4.3	6.0	3.1
Chlorophyll - a (µg/l)	-	-	46.5	29.1	37.8

APPENDIX E

Example Calculation of Water Chemistry Classification by Barica's (1975) Modified Filatov System

Example Calculation of Water Chemistry Classification by Barica's (1975) Modified Filatov System

Filatov (1948) classified natural waters on the basis of ionic concentrations (expressed as milliequivalents) and the ratio of the main anion to the sum of the second and third most abundant anions. Three types of waters are distinguished: pure, intermediate and mixed. The ionic ratio is called the coefficient of the predominant anion (Cp). Pure to True waters have Cp $\geq$ 1.9. Waters are divided into the five classes as shown in Table E.1. Concentrations of CO_3 and K are neglected in this system.

Barica's (1975) modification defines the subclasses more accurately. The subclasses are calculated according to the magnitude of cations expressed in meq.ℓ^{-1} in a similar manner to that used in anion classification. A water belongs to a true Mg subclass if the ratio Mg/(Ca+Na) (assuming that the cation abundance in order is Mg, Ca, Na) is $\geq$ 1.9. An intermediate Mg-Ca subclass if indicated by a ratio of 1.0-1.9. A mixed Mg-Ca, Ca-Mg or Mg-Na subclass is indicated if the ratio is less than 1.0.

The concentrations in mg.ℓ^{-1}, conversion factors and corresponding concentrations in meq.ℓ^{-1} of ions in Upper Devil Lake, Netley-Libau Marsh are shown in Table E.2. The concentration of an ion in meq.ℓ^{-1} is calculated by dividing the ionic concentration in mg.ℓ^{-1} by the appropriate conversion factor. For Upper Devil Lake

Table E.1. Classification of natural waters according to Filatov (1948).

Class	Name	Ionic ratio	Subclasses
I	True bicarbonate waters	$\frac{HCO_3}{SO_4 + c\ell} \geq 1.9$	calcium, magnesium and sodium waters
II	True sulfate waters	$\frac{SO_4}{c\ell + HCO_3} \geq 1.9$	calcium, magnesium and sodium waters
III	True chloride waters	$\frac{c\ell}{HCO_3 + SO_4} \geq 1.9$	calcium, magnesium and sodium waters
IV	Intermediate waters[1]	Cp=1 to 1.9	calcium, magnesium and sodium waters
V	Mixed waters[1]	Cp$\leq$1	calcium, magnesium and sodium waters

[1]Intermediate and mixed waters are named according to the most abundant ion and the second most abundant ion (chloride-bicarbonate, chloride-sulfate, sulfate-bicarbonate, sulfate-chloride, bicarbonate-sulfate and bicarbonate-chloride).

the most abundant anions in order were: HCO_3 = 3.31 meq.ℓ^{-1}, SO_4 = 1.92 meq.ℓ^{-1} and Cl = 1.47 meq.ℓ^{-1}. The appropriate anion ratio is therefore:

$$\frac{HCO}{SO_4 + Cl} = \frac{3.31}{1.92 + 1.47} = 0.98$$

Since Cp $\leq$ 1.00, Upper Devil Lake is classified as a mixed HCO_3 - SO_4 water type. The most abundant cations in Upper Devil Lake were: Calcium = 2.54 meq.ℓ^{-1}, Magnesium = 2.38 meq.ℓ^{-1} and Sodium = 2.09 meq.ℓ^{-1}. The appropriate cation ratio is therefore:

$$\frac{Ca}{Mg + Na} = \frac{2.54}{2.38 + 2.09} = 0.57$$

Upper Devil Lake is therefore classified as a mixed calcium-magnesium subtype.

Ionic conentrations in meq.ℓ^{-1} and corresponding classifications for each of the three tested Netley-Libau Marsh lakes are shown in Table E.3. Raw data values are shown in Appendix D.

Table E.2. Example calculations of meq.ℓ^{-1} from mg.ℓ^{-1} using data from Upper Devil Lake, Netley-Libau Marsh, 1981.

Ions		mg.ℓ^{-1}	conversion factor	meq/ℓ^{-1}
CATIONS	Na	48	23.00	2.09
	K	8.5	39.10	0.22
	Mg	29	12.16	2.38
	Ca	51	20.04	2.54
	Fe	0.36	27.92	0.01
ANIONS	Cl	52	35.45	1.47
	SO_4	92	48.00	1.92
	HCO_3	202	61.02	3.31
	CO_3	9.6	30.00	0.32

Table E.3. Concentrations of major ions (meq.ℓ^{-1}) in three Netley-Libau Marsh lakes. Concentrations were based on the mean of 4 samples in each area.

Ions		Upper Devil	Lower Devil	Beaconia
CATIONS	Na	2.09	1.87	0.91
	K	0.22	0.21	0.11
	Mg	2.38	2.06	1.40
	Ca	2.54	2.00	1.85
	Fe	0.01	0.02	0.02
ANIONS	Cℓ	1.47	1.30	0.59
	SO_4	1.92	1.79	0.90
	HCO_3	3.31	1.99	1.93
	CO_3	0.32	0.29	0.33
Predominant anion ratio		0.98	0.64	1.30
Classification[1]		mixed HCO_3 - SO_4	mixed HCO_3 - SO_4	intermediate HCO_3 - SO_4
Predominant cation ratio		0.57	0.53	0.80
Classification		mixed Ca-Mg	mixed Mg-Ca	mixed Ca-Mg

[1]classification was based on Barica's (1975) modified Filatov system.

APPENDIX F

Data for Numbers of Fish Caught by Experimental Fishing

Table F.1. Numbers of fish in fyke net catches from Devil's Creek in Netley-Libau Marsh, April-May, 1980. Data are number of fish caught per 24 h.

Common name	Catch Date: April 18	19	20	21	22	23	24	25	26	29	30	May 1	2	3	6	7	8	9
freshwater drum														1				
sauger																1		
walleye				3														
sucker	7	1	2		2	6		10	2	2	2		10	5	1		1	2
yellow perch	3	1	8	5	5		1		2	4	15	3	6	7	2	1		4
carp																	1	1
northern pike	30	25	19	13	19	9	3	3	7		2	1	3	7				1
quillback													1	1			1	
rock bass			1															
bullhead	~20	175	394	546	855	589	704	310	820	~566	~524	~560	~550	~500	~530	~500	~300	~300
channel catfish		1																
trout-perch					1			1					1			3	1	3
shiners										1								4
black crappie											1			1				
tadpole madtom	1																	
burbot	1														2	2		1
lamprey																1	1	1
Total	62	203	424	567	882	604	708	324	831	572	544	565	571	522	535	508	305	317

Table F.2. Numbers of fish caught in standard gillnet gangs at Netley-Libau Marsh, 1980. Data are number of fish caught per 24 h.

Common name	Area and Lift Date							
	Upper Devil Lake		Devil Creek	Lower Devil Lake		Morrison Lake	Goldeye Lake	
	Aug. 15	Aug. 21	Aug. 22	Aug. 27	Aug. 28	Sept. 4	Sept. 19	Oct. 23
freshwater drum	11	4	2	7	1	2		
goldeye	67	30	9	35	26			
mooneye								
sauger	11	25	26	111	57	24		
walleye		2	1	6				
sucker	2	6	6	19	6			
yellow perch	12	21		7	7	12		1
white bass				1				
carp	19	8	6	15	14	4	2	
bigmouth buffalo	1	2		1				
northern pike	4	5	4	5	10	5	33	7
quillback	2	1		3	3			
rock bass								
bullhead	173	105	10	49	55	4	2	
channel catfish				2				
tullibee								
whitefish								
Total	302	209	64	261	179	51	37	8

Table F.3 . Numbers of fish in fyke net catches from Netley-Libau Marsh, summer 1980. Data are number of fish caught per 24 h.

Common name	Area and date of catch						
	Upper Devil Lake				Lower Devil Lake	Morrison Lake	Goldeye Lake
	Aug. 13	Aug. 14	Aug. 19	Aug. 20	Aug. 29	Sept. 4	Sept. 12
freshwater drum	3	2	1			1	1
sauger		1	4	4	10	3	
sucker	1	1				1	
yellow perch	4	1	8		39	11	
white bass	2	2	2	2	3	2	
carp	1		1		2	1	2600
northern pike	1		1	1	6		
bullhead	34	60	12	3	276	60	39
trout-perch	1					1	
shiners	9	11	3	5	10	16	2
black crappie	26	33	4	4	10	2	
tadpole madtom			1		2	2	
Total	82	111	37	19	358	100	2642

Table F.4 . Numbers of fish caught in standard gillnet gangs at Upper Devil Lake, Netley-Libau Marsh, 1981. Data are number of fish caught per 24 h.

Common name	April	May		June			July			August		
	29	8[1]	20	2	11	23	7	14	28	12	19	27
freshwater drum		0.5	1	1	6	2	5	2		3	12	28
goldeye			2	1	9		84	98	111	63	71	70
mooneye					3		1	1				
sauger			2	3	11	9	8	13	20	15	10	36
walleye	3	2.0										3
sucker	25	4.5	1	2					2	1	2	8
yellow perch	12	14.5	21	1	1		15		34	12	8	7
white bass			1									
carp	4	9.5	12	7	4	13	10	14	7	2	9	8
bigmouth buffalo												
northern pike	20	29.0	40	11	4	6	11	7	4	4	2	1
quillback	6	4.5	6	1		3		2	2	20	6	
rock bass												
bullhead	214	185.0	216	56	121	25	57	11	109	63	68	109
channel catfish		1.0	2			3	2	3		2		
tullibee		1.0										
whitefish												
Total	284	251.50	304	83	160	61	193	151	289	185	188	270

[1] 48 hr. set corrected to 25 h duration.

Table F.5 . Numbers of fish caught in standard gillnet gangs at Lower Devil Lake, Netley-Libau Marsh, 1981. Data are number of fish caught per 24 h.

Common name	Lift Date												
	May			June			July			August			October
	14	24[1]	30[1]	9	18	30	9	21	22	5	10	25	28
freshwater drum	6	6.0	11.0	3	16	5	5	3	7	18	4	7	
goldeye	3	10.5	10.0	12	3	20	30	98	106	11	60	75	
mooneye													
sauger	6	10.5	13.0	26	42	30	8	22	39	21	46	133	
walleye	2	5.0	1.5	12					1			2	
sucker		2.5	2.0		1	1		2	2	2	4	4	
yellow perch	6	2.5	3.5	3			2	24	31	26	34	3	5
white bass													
carp	23	7.0	4.0	4	6	5	3	3	4	12	2	1	
bigmouth buffalo													
northern pike	30	25.5	12.5	4	6	10		1	2	4	3	1	32
quillback	1		1.0		1	1	8			3	5	4	
rock bass						1	1						
bullhead	106	9.5	34.0	35	22	51	11	3	17	29	25	12	1
channel catfish	2	0.5			1	1	1	4	1	2		2	
tullibee													
whitefish													1
Total	185	79.5	92.5	99	98	125	69	160	210	128	183	244	39

[1]48 h set corrected to 24 h duration.

Table F.6 . Numbers of fish caught in standard gillnet gangs at Beaconia Lake, Netley-Libau Marsh, 1981. Data are number of fish caught per 24 h.

Common name	Lift Date											
	May			June			July				August	
	12	26	27	4	16	25	16	17	24	30	8	21
freshwater drum		1	1	10	2	4	51	11	2	3	16	7
goldeye		1			1		6	4		1	11	4
mooneye							6	1				
sauger		2	1			1	10	4	3	5	15	1
walleye	1		1									
sucker	2	1									1	1
yellow perch	22	4	16	7	2	1	14	14	1	3	28	26
white bass			1				2	2		1	1	1
carp	22	10	19	15	8	2	3	6			8	5
bigmouth buffalo												
northern pike	21	7	14	13	2	3	6	4	1	5	7	5
quillback	4	4			1						3	
rock bass											1	
bullhead	2	18	39	45	10	27	31	34	2	1	8	5
channel catfish											1	
tullibee												
whitefish												
Total	74	48	92	90	26	38	129	80	9	19	100	55

Table F.7. Numbers of fish caught in 7.6 cm gillnets in the Upper Devil Lake area of Netley-Libau Marsh, 1981. Data are number of fish caught per 24 h.

Common name	April									May				June			July			August		
	10	11	12	16	17	22	23	28	29	1	3[1]	8[1]	20	2	11	23	7	14	28	12	19	27
freshwater drum														1						1	1	4
goldeye										1	1.5				2			4			21	4
mooneye																	1	1				
sauger														2	8	1				1	2	1
walleye				1		1																
sucker	4	3	1	3	3					2	2.0			2								1
yellow perch	8	8	2	10	17	3	2	5	3	12	4.0	0.5	1		1							1
white bass													1									
carp							1			1	0.5			1		2	3	1	1			1
bigmouth buffalo																						
northern pike	16	20	20	28	22	21	14	4	3	5	5.0	5.5	9	3	1	1	1		1			1
quillback														1							1	
rock bass																						
bullhead	10	15	4		4	13	7	46	50	38	16.5	50.0	19	6	31	17	4		4	4	22	22
channel catfish																	1					
tullibee																						
whitefish																						
Total	38	46	27	42	46	38	24	55	56	59	29.5	56.0	30	16	43	21	10	6	6	6	47	35

[1] 48 h set corrected to 24 h duration

Table F.8. Numbers of fish caught in combined gillnets at Netley-Libau Marsh, winter 1980-1981. Data are number of fish caught per 72 h.

Common name	Area and Lift Date: Pruden Bay Channel Mar. 16[1]	Area and Lift Date: Devil Creek Mar. 16[2]
goldeye		1
sucker	5	1
yellow perch	6	
northern pike	99	27
bullhead	18	3
Total	128	32

[1] 3.8, 5.1, 7.6, 9,5 cm meshes were set

[2] 3.8, 5.1, 7.6 cm meshes were set

APPENDIX G

Data for Total Weight of Fish Caught in Standard Gangs of Gillnets at Upper Devil, Lower Devil and Beaconia lakes, 1981

Table G.1. Total weight of fish caught in standard gangs of gillnets at Upper Devil Lake, Netley-Libau Marsh, 1981. Data are total weight (g) of fish caught per 24 h.

Common name	Lift Date: April 28	May 8[1]	May 20	June 2	June 11	June 23	July 7	July 14	July 28	August 12	August 19	August 27
freshwater drum		490	640	720	3,960	1,040	5,100	1,380		3,040	7,300	14,500
goldeye			180	80	1,100		7,940	4,980	8,340	7,020	9,120	5,720
mooneye					320		120	80				
sauger			660	980	3,880	1,940	1,860	2,160	3,160	3,020	3,140	5,270
walleye	1,600	920										1,410
sucker	31,700	7,210	920	2,640					2,360	1,200	3,080	8,380
yellow perch	2,260	1,210	2,040	100	240		2,040	80	2,560	1,020	640	780
white bass			540									
carp	12,000	32,800	42,820	35,360	16,000	45,640	27,120	35,680	17,520	3,940	14,020	14,980
northern pike	11,540	16,640	21,400	3,960	2,040	2,800	5,900	1,460	2,000	1,560	1,120	900
quillback	5,920	6,060	4,600	1,260		1,840		2,840	2,340	7,020	7,060	
rock bass					280							
bullhead	29,760	21,220	24,620	7,800	21,980	6,100	8,640	5,740	11,980	6,920	12,400	13,200
channel catfish		3,800	6,480			9,920	7,080	8,900		2,340		
tullibee		360										
whitefish												
Total	94,780	90,710	104,900	52,900	49,800	69,280	65,800	63,300	50,260	37,080	57,880	65,140

[1] 48 h set corrected to 24 h duration.

Table G.2. Total weight of fish caught in standard gangs of gillnets at Lower Devil Lake, Netley-Libau Marsh, 1981. Data are total weight (g) of fish caught per 24 h.

Common name	Lift Date												
	May			June			July			August			October
	14	24[1]	30[1]	9	18	30	9	21	22	5	10	25	28[2]
freshwater drum	5,620	4,420	8,210	2,680	8,580	4,100	4,040	2,220	4,380	8,780	1,220	4,280	
goldeye	940	1,400	1,390	1,240	260	2,240	3,360	7,160	9,000	1,320	4,420	12,200	
mooneye													
sauger	1,360	2,455	2,350	3,560	9,240	5,860	1,790	4,340	7,180	5,710	9,960	22,200	
walleye	860	1,040	340	1,500					380			740	
sucker		2,550	2,280		2,120	1,540		1,160	2,660	1,820	4,140	3,600	
yellow perch	340	270	420	3,060			260	1,700	1,740	1,200	2,680	300	
white bass													
carp	79,160	27,980	12,580	13,770	30,560	13,300	10,260	5,880	8,420	23,980	8,670	2,340	
bigmouth buffalo													
northern pike	19,900	11,175	10,090	2,180	3,080	3,620	2,660	760	360	1,140	6,120	420	21,120
quillback	640		670		520	1,880				2,280	3,220	3,060	
rock bass						240	180						
bullhead	17,100	1,850	6,530	8,480	7,780	14,700	3,200	600	6,000	5,660	4,280	2,320	300
channel catfish	6,280	790			2,220	1,880	5,300	6,280	360	1,540		1,300	
tullibee													
whitefish													20
Total	132,200	53,930	44,860	36,470	64,360	49,360	31,050	30,100	40,480	53,430	44,710	52,760	21,440

[1] 48 h set corrected to 24 h duration.

[2] 5 perch were captured in the standard gang (Table F.5). Mesh size of capture was not recorded and the fish were not weighed. The 5 perch were donated to a University of Winnipeg undergraduate research project.

Table G.3. Total weight of fish caught in standard gangs of gillnets at Beaconia Lake, Netley-Libau Marsh, 1981. Data are total weight (g) of fish caught per 24 h.

Common name	Lift Date											
	May			June			July				August	
	12	26	27	4	16	25	16	17	24	30	8	21
freshwater drum		700	800	8,060	1,100	2,460	32,800	9,880	1,380	2,480	9,860	4,540
goldeye		120			200		200	400		260	1,520	440
mooneye							140	80				
sauger		280	120			460	1,820	420	560	920	4,000	120
walleye	1,420		300									
sucker	2,670	1,060									1,400	4,020
yellow perch	2,680	200	2,550	240	300	320	1,500	2,120	240	320	2,000	2,860
white bass			680				180	360		80	120	160
carp	94,820	54,580	97,360	71,620	26,660	6,320	12,860	14,620			15,740	17,660
bigmouth buffalo												
northern pike	13,400	2,560	6,440	4,240	780	940	2,220	860	400	2,580	3,020	2,140
quillback	3,980	3,580			1,000						2,160	
rock bass											100	
bullhead	1,000	3,760	7,960	11,580	2,620	7,460	11,900	5,980	660	580	2,420	900
channel catfish											760	
tullibee												
whitefish												
Total	119,970	66,840	116,210	95,740	32,660	17,960	63,440	34,720	3,240	7,220	43,100	32,840

APPENDIX H

Example Calculation of Whittaker and Fairbanks' Similarity Index (PS)

Example Calculation of Whittaker and Fairbanks' Similarity Index (PS)

Horn (1980) gives the Whittaker and Fairbanks (1958) similarity index (PS) as:

$$PS = 100(1.0-0.5\ \Sigma|P_{ia} - P_{ib}|)$$

Where P_{ia} is the proportion of individuals (or biomass) in the i^{th} species of sample a and P_{ib} the same for sample b. Percentage similarity ranges from 0, when two samples contain no species in common, to 100, when the two samples are identical in both species composition and relative abundance. The summation calculation is carried out as shown in the table below. The value of PS for Netley-Libau Marsh, August versus October, is then: PS = 100(1.0-0.5 x 1.6794 = 16.03%.

Table H.1.

Species	August (P_{ia})	October (P_{ib})	$\lvert P_{ia} - P_{ib} \rvert$
freshwater drum	0.0601		0.0601
goldeye	0.2051		0.2051
sauger	0.2079		0.2079
walleye	0.0052		0.0052
sucker	0.0279		0.0279
yellow perch	0.1149	0.2166	0.0117
white bass	0.0022		0.0022
carp	0.0538		0.0538
northern pike	0.0326	0.8478	0.8152
quillback	0.0213		0.0213
rock bass	0.0008		0.0008
bullhead	0.2629	0.0128	0.2501
channel catfish	0.0040		0.0040
whitefish		0.0128	0.0128
bigmouth buffalo	0.0013		0.0013
		$\Sigma\lvert P_{ia} - P_{ib} \rvert$	=1.6794

APPENDIX I

Example Calculation of Mountford's (1962) Information Analysis

Example Calculation of Mountford's (1962) Information Analysis

Suppose that there are five sampling sites A,B,C,D,E, and that a species composition has been determined for each of them. Some index of similarity (e.g. Whittaker and Fairbanks index) must be calculated for all possible comparisons between them. For five sites a total of ten indices must be calculated. The resulting indices are arranged in a trellis diagram as shown in the hypothetical example below:

	B	C	D	E
A	7.4	11.3	9.5	10.3
B		13.6	14.4	11.7
C			13.5	11.9
D				6.8

The index with highest value determines the first combination. In this example sites B and D (PS = 14.4%) are most similar and form the first group. New similarity indices are then calculated between the combined group and the remaining sites. There are two applicable formulas. The general formula for the comparison of m sites with another (C) is:

$$I(A_1A_2A_3\ldots A_m{:}C) = \frac{I(A_1C)+I(A_2C)+I(A_3C)+\ldots I(A_mC)}{m}$$

This formula can be extended to compare groups (e.g. group A_1A_2 compared to group B_1B_2) as:

$$I(A_1A_2{:}B_1B_2) = \frac{I(A_1B_1)+I(A_1B_2)+I(A_2B_1)+I(A_2B_2)}{4}$$

The general formula is:

$$\frac{1}{mn} \sum_{i=1}^{m} \sum_{j=1}^{n} I(A_i B_j)$$

In this example the calculation of the new index of similarity between group BD and site E is:

$$I(BD:E) = \frac{I(BE)+I(DE)}{2}$$

$$= \frac{11.7+6.8}{2}$$

$$= 9.3$$

A new trellis diagram is then formed as shown below:

	BD	C	E
A	8.5	11.3	10.3
BD		13.6	9.3
C			11.9

The highest value is now I(BD:C) = 13.6 and a new group is formed (BDC). New indices are recalculated and a new trellis diagram is formed as shown below:

	BDC	E
A	9.4	10.3
BDC		10.1

The highest value is I(A:E) = 10.3 so that a new group (AE) is formed. The final stage in this example is a comparison of the two groups (BDC and AE). The calculated value of the index is: I(BDC:AE) = 9.8. The stepwise agglomeration of similarity indices are best represented pictorially by a dendogram (Fig. I.7). The horizontal positioning of sampling sites is governed by the

order of combination. The vertical positioning of nodes is determined by the magnitude of the similarity index which combined the sampling sites. The combination process is completely objective but any meaning given to it must still be judged according to biological considerations. If sites BD and C were from a riffle stream section while sites E and A were from pool sections the investigator might suggest that distinct communities occur in riffle and pool areas. On the other hand, if sites BC and E were riffle areas while sites D and A were pool areas the investigator may suggest that riffle and pool areas are not important and that other factors are more important determinants of community structure.

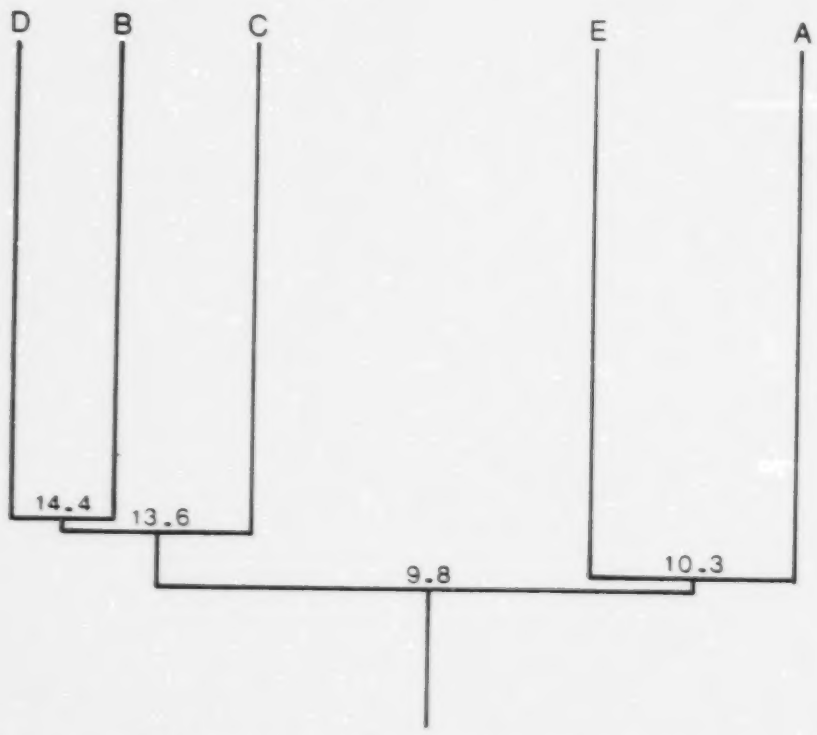

Fig. I.7. Classification of five hypothetical sampling sites based on indices of similarity between them (after Mountford 1962).

APPENDIX J

Example Calculation of Shannon Wiener Diversity Index (H')

Example Calculation of Shannon-Weiner Diversity Index (H')

Horn (1980) gives the Shannon-Weiner Information function H' as:

$$H' = - \sum_{i=1} P_i \log_e P_i$$

Where P_i is the proportion of individuals (or biomass) in the i^{th} species.

The table below shows calculations for the July species composition at Netley-Libau Marsh.

species	P_i	$\log_e P_i$	$P_i \times \log_e P_i$
freshwater drum	0.1076	-2.2293	-0.2399
goldeye	0.3170	-1.1489	-0.3642
mooneye	0.0070	-4.9618	-0.0347
sauger	0.1360	-1.9951	-0.2713
walleye	0.0005	-7.6009	-0.0038
sucker	0.0029	-5.8430	-0.0169
yellow perch	0.1074	-2.2312	-0.2396
white bass	0.0093	-4.6777	-0.0435
carp	0.0348	-3.3581	-0.1169
northern pike	0.0720	-2.6311	-0.1894
quillback	0.0020	-6.2146	-0.0124
rock bass	0.0015	-6.5023	-0.0098
bullhead	0.1945	-1.6373	-0.3185
channel catfish	0.0075	-4.8929	-0.0367
Total	1.0000		-1.8976

The sum at the bottom of the fourth column, with sign changed is H'. In this case the measure of species composition diversity is H'=1.90.

Values for the Shannon-Weiner diversity index for each month of combined 1980-1981 gillnet catches are shown in the table below.

Month	H'
March	0.69
April	1.24
May	1.83
June	1.69
July	1.90
August	1.95
September	1.38
October	0.51

[1]Diversity indices were calculated from combined gillnetting, 1980-1981.

APPENDIX K

Walleye Tagging Results from Netley-Libau Marsh

Table K.1. Walleye tagging results from Netley-Libau Marsh, April 1980.

tags issued						tags returned			
Tag. No.	Tagging Location	Date	Sex[1]	Mat[2]	Fork Length (mm)	Return Location	Date	Days at large	Approx. dist. travelled (km)[4]
1) N 12519	Devil Creek at Hwy. 59	Apr. 21/80	M	ripe	382				
2) N 12520	Devil Creek at Hwy. 59	Apr. 21/80	M	ripe	384	Lockport Dam[3]	Sept. 22/80	154	38
3) N 12521	Devil Creek at Hwy. 59	Apr. 21/80	U	hard	592	Lockport Dam	Jan. 23/81	277	38
4) N 09502	Wavey Creek E Hwy. 09	Apr. 25/80	U	hard	496				
5) N 09503	Wavey Creek E Hwy. 09	Apr. 25/80	M	ripe	398				
6) N 09504	Wavey Creek E Hwy. 09	Apr. 25/80	M	ripe	426	L. Wpg. Beaconia area[5]	Oct. 06/81	529	30

[1] M = male, U = unknown

[2] ripe = milt or eggs flow from vent when fish squeezed, hard = no milt or eggs flow

[3] additional recapture information: length = 18 in (457 mm) girth = 9 in (229 mm) weight = 2.5 lbs (821 gm)
∴ growth = Approx. 73 mm (3 in)

[4] distance travelled is the shortest distance by water between the tagging and recapture site

[5] additional recapture information: weight 2.72 kg (6 lbs)

APPENDIX L

Stomach Contents Data

Table L.1. Stomach contents of sauger from Netley-Libau Marsh, 1980-1981.

food category	number of stomachs[1]	% number of stomachs
empty	53	46.09
chyme	2	1.74
unidentified fish	22	19.13
perch	22	19.13
shiners	18	15.05
bullhead	2	1.74
carp	2	1.74
black crappie	2	1.74
bigmouth buffalo	1	0.87
crayfish	1	0.87
catfish	1	0.87
number of stomachs examined	115	

[1]Results from each stomach, in some cases, fitted in several categories and therefore number by category does not add up to total stomachs. Percentages were calculated as: (number of occurrences in category ÷ number of stomachs examined) 100.

Table L.2. Stomach contents of northern pike from Netley-Libau Marsh, 1980-1981.

food category	number of stomachs[1]	% number of stomachs
empty	60	27.78
chyme	1	0.46
unidentified fish	19	8.80
perch	10	4.63
white sucker	1	0.46
shiners	9	4.17
black crappie	2	0.93
white bass	3	1.39
northern pike	2	0.93
carp	36	16.67
dragonfly nymphs	1	0.46
mayfly nymphs[2]	81	37.50
crayfish	1	0.46
chironomid larvae	1	0.46
number of stomachs examined	216	

[1]Results from each stomach, in some cases, fitted in several categories and therefore number by category does not add up to total stomachs. Percentages were calculated as: (number of occurrences in category ÷ number of stomachs examined).

[2]mayfly nymphs were found in winter catches only. 81 stomachs with mayflies represent ∿ 60% of stomachs examined during winter.

APPENDIX M

Preliminary Tabulations and Analyses for Population Statistics

Table M.1. Age compositions of Netley-Libau Marsh saugers, northern pike and goldeye.

Age (years)	sauger			northern pike			goldeye		
	n	Log_e	%	n	Log_e	%	n	Log_e	%
0							2	0.69	2.38
1	24	3.18	3.08	19	2.94	3.20	31	3.43	36.90
2	263	5.57	33.72	170	5.14	28.62	36	3.58	42.86
3	210	5.35	26.92	186	5.23	31.30	11	2.40	13.10
4	137	4.92	17.56	148	5.00	24.91	3	1.10	3.57
5	100	4.61	12.82	39	3.66	6.57	1	0.00	1.19
6	39	3.66	5.00	18	2.89	3.03			
7	5	1.61	0.64	7	1.95	1.18			
8	2	0.69	0.26	2	0.69	0.34			
9				3	1.10	0.51			
10				2	0.69	0.34			
Total	780			594			84		

Table M.2 Mortality and survival rates estimated by regression and the Robson-Chapman method for sauger, northern pike and goldeye from the Netley-Libau Marsh, 1980-1981.

Species	Robson-Chapman				Regression			
	Z	A	S ± 2SE	Ages	Z	A	S	Ages
sauger	1.27	0.72	0.15 < 0.28 < 0.40	5-8	0.98	0.62	0.38	3-8
northern pike	0.97	0.62	0.27 < 0.38 < 0.48	4-10	0.72	0.51	0.38	4-10
goldeye	1.24	0.71	0.07 < 0.29 < 0.50	2-5	1.20	0.70	0.30	3-5

Table M.3. Length-weight relationships of saugers, northern pike and goldeye from Netley-Libau Marsh, 1980-1981[1].

Species	Length-weight equation	Correlation coefficient	Test F ratio, d.f. and significance at P=0.05
sauger	$\log_e$ weight = -10.827+2.887 $\log_e$ length	0.999	5111.97(1,6) significant
northern pike	$\log_e$ weight = -11.686+2.997 $\log_e$ length	0.995	877.52(1,8) significant
goldeye	$\log_e$ weight = -13.607+3.414 $\log_e$ length	0.997	593.93(1,4) significant

[1] regressions fitted to age specific mean lengths and weights of combined 1980-1981 catches.

Table M.4. Age-specific mean lengths and weights of Netley-Libau Marsh sauger, northern pike and goldeye, 1980-1981.

Age (years)	sauger			northern pike			goldeye		
	n	$\bar{l}$	$\bar{w}$	n	$\bar{l}$	$\bar{w}$	n	$\bar{l}$	$\bar{w}$
0							2	127.00	17.50
1	24	191.92	75.75	19	281.68	203.16	31	175.97	59.52
2	263	226.81	126.80	170	347.20	330.53	36	219.00	128.89
3	210	256.90	183.33	186	394.70	490.75	11	253.82	191.82
4	137	305.92	291.99	148	425.07	610.42	3	254.33	223.33
5	100	317.48	336.70	39	463.13	767.18	1	302.00	320.00
6	39	323.44	366.41	18	562.44	1407.78			
7	5	375.20	536.00	7	628.00	2294.29			
8	2	411.00	680.00	2	679.00	3120.00			
9				3	699.00	2480.00			
10				2	814.50	4290.00			

Table M.5. Linear equations of Walford plots for sauger, northern pike and goldeye from Netley-Libau Marsh, 1980-1981.

Species	Walford equation $L_{t+1} = (a+b)\ L_t$	L_∞ (mm)	Correlation coefficient	test F ratio and d.f.
sauger	$L_{t+1} = 87.47+0.77\ L_{t_1}$	380.30	0.96	31.72(1,3)
northern pike	$L_{t+1} = 82.05+0.90\ L_{t_2}$	820.50	1.00	707.24(1,3)
goldeye	$L_{t+1} = 141.26+0.47\ L_{t_3}$	266.53	0.90	4.28(1,1)

[1] ages 7-8 deleted

[2] ages 6,7,10 deleted

[3] ages 0,5 deleted

Table M.6. Relationships of $\log_e (L_\infty - L_t)$ and t for sauger, northern pike and goldeye from Netley-Libau Marsh, 1980-1981.

Species	$\text{Log}_e (L_\infty - L_t) = a-bt$	Correlation coefficient	test F ratio, d.f. and significance
sauger	$\log_e (380.30-L_t) = 5.51-0.26t$	0.98	93.83 (1,4) $p<0.01$
northern pike	$\log_e (820.50-L_t) = 6.62-0.20t$	0.97	89.30 (1,5) $p<0.01$
goldeye	$\log_e (266.53-L_t) = 5.19-0.74t$	0.95	19.08 (1,2) $p<0.01$

[1] ages 7,8 deleted

[2] ages 6,7,10 deleted

[3] ages 0,5 deleted

Table M.7. Maturity schedule of Netley-Libau Marsh sauger, 1980-1981.

Scale age (years)	No. immature			No. mature			% mature		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
1	9	10	19	2	1	3	18.18	9.09	14.29
2	64	71	135	42	48	90	39.62	40.34	40.00
3	25	31	56	73	74	147	74.49	70.48	72.41
4	1	4	5	56	74	130	98.25	94.87	96.30
5	1	2	3	36	60	96	97.30	96.77	96.97
6		1	1	11	25	36	100.00	96.15	97,30
7				2	3	5		100.00	100.00
8				1	1	2			

- sex ratio: 1.25 female: 1 male -

Table M.8. Maturity schedule of Netley-Libau Marsh northern pike, 1980-1981.

cleithrum age (years)	No. immature			No. mature			% mature		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
1	4	3	7	6	5	11	60.00	62.50	61.11
2	12	16	28	87	53	140	87.88	76.81	83.33
3	11	8	19	90	73	163	89.11	90.12	89.56
4	5	5	10	70	61	131	93.33	93.85	92.91
5	2	2	4	19	14	33	90.48	87.50	89.19
6				9	9	18	100.00	100.00	100.00
7				1	6	7			
8				1	1	2			
9					3	3			
10					2	2			

- sex ratio 0.82 female: 1 male -

Table M.9. Maturity curves of Netley-Libau Marsh sauger and northern pike, 1980-1981 combined.

Species	Type	Maturity Curve $-\log_e \frac{(K-Y)}{Y}$=a+b.age	Correlation coefficient	Age at 50% mature	Test F value and d.f.
sauger	males	Y= -3.031+1.461X	0.953	2.07	29.87(1,3)
	females	Y= -2.815+1.172X	0.948	2.40	35.84(1,4)
	combined	Y= -2.567+1.165X	0.955	2.20	41.36(1,4)
pike	males	Y= 0.571+0.435X	0.801	1.31	5.38(1,3)
	females	Y= 0.399+0.440X	0.798	0.91	5.26(1,3)
	combined	Y= 0.495+0.428X	0.829	1.16	6.58(1,3)

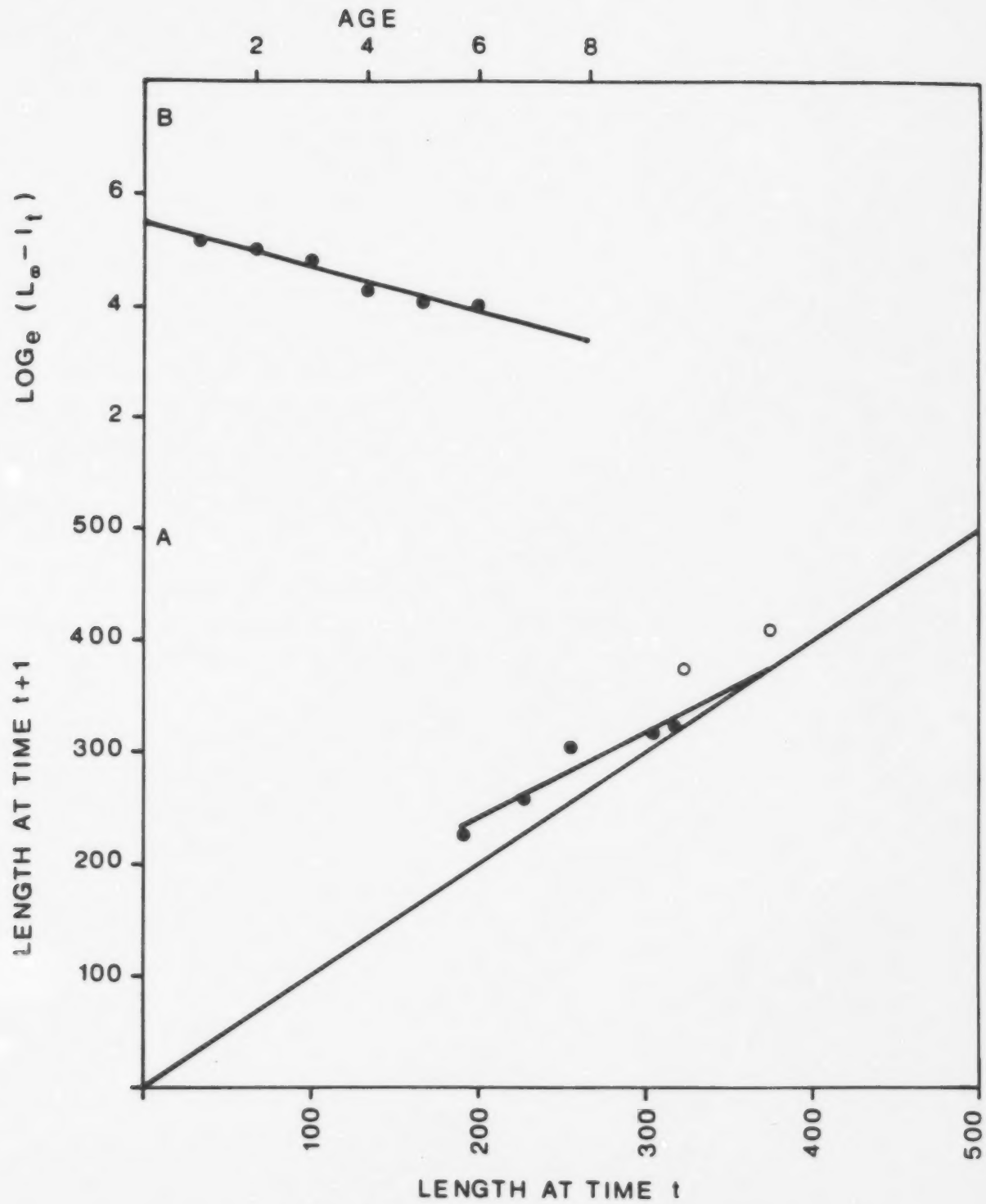

Fig. M.1. (A) Walford graph for length of sauger of Netley-Libau Marsh, 1980-1981. The first point on the left is age 2 plotted against age 1. Open circles show points not included in calculations.
(B) Log_e ($L_\infty - l_t$) plotted against age for L_∞ = 380.30mm.

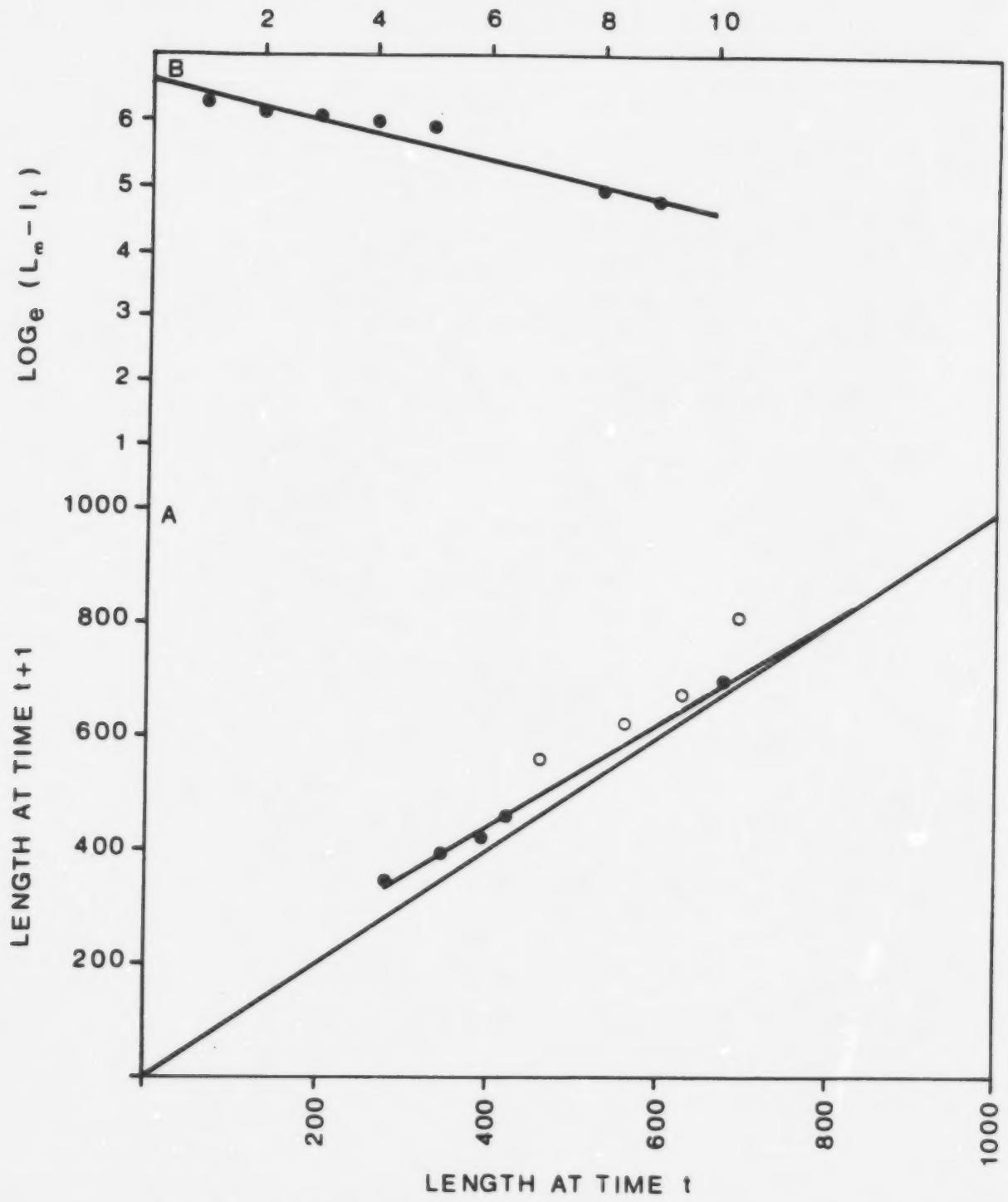

Fig. M.2. (A) Walford graph for length of northern pike of Netley-Libau Marsh, 1980-1981. The first point on the left is age 2 plotted against age 1. Open circles show points not included in calculations.
(B) Log_e $(L_\infty - l_t)$ plotted against age for L_∞ = 820.50mm.

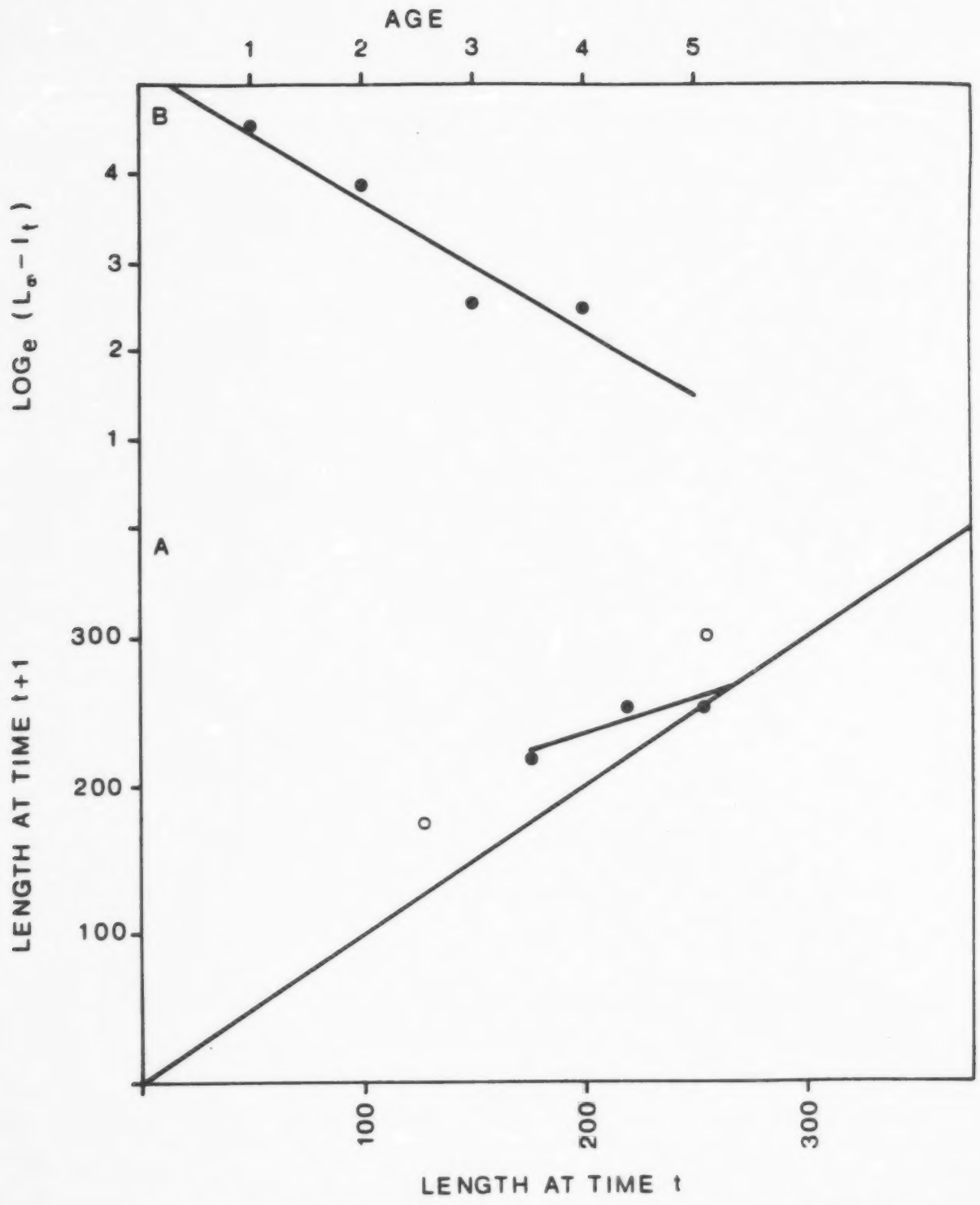

Fig. M.3. (A) Walford growth for length of goldeye of Netley-Libau Marsh, 1980. The first point on the left is age 1 plotted against age 0. Open circles show points not included in calculations.
(B) Log_e $(L_\infty - l_t)$ plotted against age for L_∞ = 266.53mm.

Table M.10. Scale ages and corresponding mean otolith ages of sauger from Netley-Libau Marsh 1980-1981.

scale age (years)	Mean otolith age ± 2 S.D. (years)	Number of fish
1	0.44 < 1.46 < 2.48	26
2	1.18 < 2.22 < 3.26	236
3	1.76 < 3.08 < 4.40	170
4	2.76 < 4.38 < 6.00	69
5	3.65 < 5.45 < 7.25	76
6	4.28 < 6.20 < 8.12	35
7	7.00 < 9.20 < 11.40	5
8	10.00[1]	2

[1] standard deviation = 0.

Table M.11. Scale ages and corresponding mean pelvic fin ages of goldeye from Netley-Libau Marsh, 1980.

Scale age (years)	Mean pelvic fin ages ± 2 S.D.[1] (years)	Number of fish
0	0	3
1	0.01 < 0.91 < 1.81	35
2	0.27 < 1.31 < 2.35	35
3	0.58 < 2.00 < 3.42	9
4	-0.67 < 3.50 <11.25	2
5	5	1

[1]S.D. = Standard Deviation

APPENDIX N

Comparison of Lake Winnipeg and Netley-Libau Marsh Sauger Population Statistics

Table N.1. Summary of population statistics for sauger from Lake Winnipeg[1] and Netley-Libau Marsh.

Year	Lake Winnipeg			Netley-Libau Marsh (1980-1981 combined)
	South basin	Channel	North basin	
		Modal age		
1979	4	4	8	
1980	6	5	7	2
1981	6	no data	6	
		Age range		
1979	2-8	2-10	4-20	
1980	1-10	1-11	3-14	1-8
1981	1-10	no data	2-13	
		Instantaneous mortality rate (Z)		
1979	2.07	0.82	0.54	
1980	1.13	1.20	0.73	1.27
1981	1.85	no data	0.85	
		Survival rate (S)		
1979	0.03<0.13<0.22	0.28<0.44<0.60	0.47<0.58<0.69	
1980	-0.02<0.32<0.66	-9.76×10^{-3}<0.30<0.60	0.25<0.47<0.69	0.13<0.28<0.40
1981	-0.13<0.15<0.44	no data	0.17<0.43<0.69	
		Length-weight relationship		
1979	$\hat{LnW}$=-8.84+2.54LnL	$\hat{LnW}$=-10.94+2.89LnL	$\hat{LnW}$=-11.97+3.10LnL	
1980	$\hat{LnW}$=-12.92+3.25LnL	$\hat{LnW}$=-11.88+3.06LnL	$\hat{LnW}$=-11.56+3.03LnL	$\hat{LnW}$=-10.83+2.89LnL
1981	$\hat{LnW}$=-11.62+3.04LnL	- no data -	$\hat{LnW}$=-12.26+3.14LnL	
		Growth in length		
1979	$L_t=301(1-e^{-1.69(t+1.45)})$	$L_t=361(1-e^{-0.29(t-0.07)})$	$L_t=402(1-e^{-0.29(t-0.36)})$	
1980	$L_t=334(1-e^{-0.38(t=0.65)})$	$L_t=367(1-e^{-0.23(t-1.36)})$	(a) $L_t=425(1-e^{-0.24(t-0.19)})$ (b) $L_t=500(1-e^{-0.15(t+0.84)})$	$L_t=380(1-e^{-0.26(t+1.66)})$
1981	(a) $L_t=400(1-e^{-0.19(t+1.67)})$ (b) $L_t=368(1-e^{-0.23(t+1.01)})$	- no data -	(a) $L_t=415(1-e^{-0.28(t+0.76)})$ (b) $L_t=-88\ (1-e^{-0.12(t+4.00)})$	
		Age at maturity		
1979	♂=6.22 ♀=5.34	- no data - - no data -	♂=7.15 ♀=9.69	
1980	♀=3.71 AF[2]=3.58	♀=5.32 AF=5.17	♀=5.34 AF=4.61	♂=2.07 ♀=2.40 AF=2.20
1981	♂=3.72 ♀=4.82 AF=4.18	- no data - - no data - - no data -	♂=3.61 ♀=4.26 AF=3.80	
		Maturity rate equation		
1979	♂:Y=-0.59+0.09X ♀:Y=-1.69+0.32X	- no data - - no data -	0=Y=-2.33+0.33X ♀=Y=-0.68+0.07X	
1980	♂:Y=-5.43+1.46X AF:Y=-5.76+1.61X	0:Y=-6.07+1.14X AF:Y=-5.11+0.99X	♀=Y=-5.87+1.10X AF:Y=-3.74+0.81X	♂:Y=-3.03+1.46X ♀:Y=-2.82+1.17X AF:Y=-2.57+1.17X
1981	♂:Y=-3.62+0.97X ♀:Y=-8.32+1.72X AF:Y=-481+1.15X	- no data - - no data - - no data -	♂:Y=-3.72+1.03X ♀:Y=-3.31+0.78X AF:Y=-3.03+0.80X	

[1] Lake Winnipeg data from Lysack (1980,1981,1982)

[2] AF=all fish